Multivariate analyses of cranial morphology inform the taxonomy and evolution of geomyoid rodents

Research Thesis

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by

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ABSTRACT

Morphological analyses are critical to quantify variation within and across species, identify taxa, understand species relationships, and shed light on evolutionary patterns. This work is particularly important in groups that display great morphological disparity. Such is the case in geomyoid rodents, a group that includes two of the most species-rich families of rodents in North America: the Geomyidae (pocket gophers) and the Heteromyidae (kangaroo rats, pocket mice, and their relatives). We assessed variation in skull morphology (including both shape and size) among geomyoids to test the hypothesis that there are statistically significant differences in cranial measurements at the family, genus, and species-levels. Our sample includes a total of 886 specimens representing all geomyoid genera and a total of 39 species. We used the geometric mean of all specimens in the dataset to compare size across taxa. We also used 14 measurements of the skull and lower jaw normalized for size and multivariate statistical methods to compare shape among and within taxa. Our results show that cranial measurements enable the distinction of geomyoids at the family, genus, and species levels. There is a larger amount of size variation within Geomyidae than within Heteromyidae. Our phylomorphospace analysis shows that the skull shape of the common ancestor of all geomyoids was more similar to the common ancestor of heteromyids than that of geomyids. Geomyid skulls display negative allometry whereas heteromyid skulls display positive allometry. Within heteromyids, dipodomyines and non-dipodomyines show significantly different allometric patterns.

INTRODUCTION

Rodentia is the most species-rich order of mammals (Burgin et al., 2018). The families Heteromyidae and Geomyidae form the superfamily Geomyoidea and, together with Castoridae, are members of the suborder Castorimorpha (Fabre et al. 2012; Upham et al. 2019; D'Elía et al. 2019). Geomyoidea includes 109 species and as such, is one of the most species-rich clades of rodents (Mammal Diversity Database 2020; D'Elía et al. 2019). The clade also includes large amounts of ecological variation. Thus, geomyoids are found among many different habitats (Campbell et al. 2012). They also display diverse locomotory modes. Geomyidae are fossorial whereas Heteromyidae are ricochetal, terrestrial, or semi-fossorial (Bartholomew and Caswell 1951; Bartholomew and Cary 1954; Djawdan 1993; Roberts et al. 1997; Wilkins and Roberts 2007; Calede et al. 2017). Geomyoid diet consists of roots and tubers, grass, fruit, and seeds (Connior 2011; Martinez-Gallardo and Sánchez-Cordero 1993). The great taxonomic and ecological diversities of geomyoids is associated with an incredible disparity of cranial morphologies (Hafner and Hafner 1988). Certainly, the diet and locomotion of rodents are linked to cranial morphology (Verde Arregoitia et al. 2017). The link between cranial morphology and taxonomy in geomyoids remains to be rigorously investigated.

The systematics of Geomyoidea have been the subject of much attention (e.g., Demastes et al. 2002; Belfiore et al. 2008; Spradling et al. 2016; Riddle et al. 2014; Alexander and Riddle 2005; Mathis et al. 2014; Hafner et al. 2008, 2009). Based on molecular (Upham et al. 2021), immunological (Hafner 1993), and paleontological data (Wahlert 1991), the split between Geomyidae and Heteromyidae has been placed in the Oligocene; the oldest known heteromyid is *Paratrogomys; Gregorymys* is the oldest geomyid (Flynn et al. 2008; Guerrero-Arenas et al. 2020; Calede and Rasmussen 2020; Marivaux et al. 2021). The family Heteromyidae is divided into the subfamilies Heteromyinae; composed of *Heteromys*, *Dipodomyinae*; composed of *Dipodomys* and *Microdipodops*, and Perognathinae; composed of *Chaetodipus* and *Perognathus*; living Geomyidae consist only of a single subfamily, the Geomyinae (Honeycutt and Williams 1982). Despite the extensive amount of work dedicated to the systematics of Geomyoidea, phylogenetic uncertainty remains and the monophyly of Heteromyidae exclusive of Geomyidae is still debated (Alexander and Riddle 2005; Hafner et al. 2007; Fabre et al. 2012). A resolved phylogeny for Geomyoidea would enable analyses of evolutionary patterns that have often only been described qualitatively (e.g., Hafner and Hafner 1988). Morphology is one tool that has

been used in the identification of geomyoid species and their relationships (e.g., Alexander and Riddle, 2005; Anderson and Gutierrez, 2009).

Cranial morphology has already been demonstrated to be taxonomically useful in geomyoids. Thus, the study of the crania of *Heteromys* has enabled the recognition of new species and taxonomic revisions (Anderson and Timm 2006; Anderson and Jarrín-V 2002; Anderson 2003). Spradling et al. (2016) used cranial morphology to clarify the taxonomy of *Heterogeomys* and *Orthogeomys*. Riddle et al. (2014) used morphometrics to explore cryptic diversity within a species of *Perognathus*. We are analyzing morphological variation across and within a large number of geomyoid species to determine the potential of morphology to inform taxonomy and quantify morphological disparity and morphospace overlap across species. Combined with phylogenetics, our morphological data enable an initial study of the pattern of cranial shape evolution within Geomyoidea. This work completes prior morphological analyses of dental morphology undertaken by Calede and Glusman (2017), Carrasco (2000), and Wyatt et al. (2021). In particular, Calede and Glusman (2017) as well as Wyatt et al. (2021) used geometric morphometrics to test the hypothesis that tooth shape informs levels of morphological variation and taxonomic affinities. Our study is therefore an opportunity to compare the potential of tooth morphology to that of skull morphology in deciphering geomyoid morphological variation. Additionally, our study builds upon Calede and Brown (2021), which looked at cranial shape and size sexual dimorphism across geomyoid taxa, finding that there is no single explanation for the evolution of sexual dimorphism in geomyoids, but instead, that numerous evolutionary events produced the observed variation. Here we use cranial measurements from a broad sample of 39 geomyoid species represented by 886 specimens and pre-existing phylogenetic information to investigate the relationship between morphology and phylogeny. A large sample size enables the consideration of intraspecific variation. We specifically test the following hypotheses: (1) size is an informative characteristic for geomyoid taxonomy; (2) cranial morphology can be used to distinguish Heteromyidae and Geomyidae at the family, genus, and species level; (3) species within the Geomyidae family display high levels of convergence in skull shape; (4) Heteromyidae has higher morphological disparity than Geomyidae; (5) changes in allometric relationships between skull size and shape help explain the evolution of peculiar cranial morphologies within Heteromyidae, particularly in Dipodomyinae.

MATERIALS AND METHODS

Taxonomic Sampling and Data Collection

Our sample is built upon that of Calede and Brown (2021), which analyzed sexual dimorphism in cranial size and shape in geomyoids. It includes a total of 886 specimens distributed across the two living families of geomyoids: Geomyidae and Heteromyidae (Table 1). Data were collected from 396 specimens of Geomyidae representing all seven genera and 17 of 41 species as well as 490 specimens of Heteromyidae representing all five genera and 22 of 68 species (mean 22.7 per species, median 18). We only analyzed data from adult specimens to avoid ontogenetic effects on morphology. We included both males and females for every taxon, sampling a subequal or equal number of specimens for both sexes whenever possible.

For each specimen, we measured a total of 14 cranial variables representing skull shape in three dimensions (length, width, and depth) across four regions of the cranium (rostrum, palate, braincase, and lower jaw; Table 2). Measurements were taken from prior analyses of morphological variation in geomyoids (see Calede and Brown 2021), photos of the specimens using ImageJ 1.51 (Schneider et al., 2012), or directly from specimens using Mitutoyo CD-6" CSX digital calipers (measured to the nearest 0.1 mm). All measurements were logged prior to analyses except for the calculations of the multivariate coefficient of variation (see below) for which negative log values would skew the results. For each specimen, we calculated the geometric mean of the measurements by using the square root of the product of all 14 measurements (Jungers et al. 1995, Madar et al. 2002). We used the geometric mean to normalize the data for size by dividing each measurement by the geometric mean resulting in a new measurement that represents form and can be compared across specimens of different sizes (Calede and Brown 2021). Measurement errors for a large section of this dataset have already been determined to not affect the results of shape and size analyzes (Calede and Brown 2021). The complete dataset is being analyzed to test other hypotheses, but it can be obtained from the corresponding author on reasonable request. A complete list of the specimens measured is provided in Appendix 1.

The phylogenetic framework we used is from Fabre et al. (2012). We randomly selected 100 trees from the 1000 time-calibrated trees developed by Price and Hopkins (2015) and pruned the

trees to keep taxa with morphological data using the package APE 5.5 (Paradis et al. 2004) in R 4.0.5 (R Core Team 2019).

Analyses of Size and Shape

We used two one-way analyses of variance (ANOVA) to assess statistical differences in geometric means among the 17 species of geomyids and the 22 species of heteromyids studied. The significant ANOVAs were followed by post-hoc Tukey honest significance tests to determine significant pairwise differences.

The entire dataset of measurements (not including the geometric mean) was included in a principal component analysis (PCA) to explore morphospace occupation at the superfamily level (Geomyoidea). The PCA was repeated at lower taxonomic levels to assess similarities and differences in cranial morphology among genera and species. Eigenvalues were determined for each of the principal components identified and eigenvectors were used to assess the weight of cranial features on the overall eigenvalue. We only retained significant axes in our analyses. The determination was made using a Monte Carlo randomization test run in biostats (McGarigal 2015). PCAs were followed by a multivariate analysis of variance (MANOVA), to assess statistical differences. When significant, MANOVAs were followed by ANOVAs and post hoc Tukey tests as appropriate to interpret the pattern of morphological variation. We predicted that there would be statistically significant differences in cranial measurements among taxa.

We used a phylomorphospace to overlay phylogenetic information on the mean PC scores for each species using phytools 0.7-80 (Revell 2012, 2013). This enabled us to explore the pattern of evolution of cranial morphology within Geomyoidea.

The transformed cranial variables were also used in a series of canonical variate analyses (CVA) to determine the usefulness of skull morphology in classifying specimens into their taxonomic groups. CVAs were run at the family, genus, and species levels. We used a jackknife to assess to how reliably each taxon in the training set can be assigned to their *a priori* taxonomic category (Strauss 2010). We predicted that cranial measurements do enable the reliable identification of unidentified specimens at the family, genus, and species levels.

Morphological variation

We calculated the multivariate coefficient of variation (multiCV) for each family, genus, and species to compare variability across taxa. We followed the approach of Lal et al. (2015) originally described by Van Valen (1978) and used by Soulé and Zegers (1996) in a prior analysis of the morphological variation within the geomyid taxon *Thomomys bottae.* The use of a multivariate measure of variation enables the integration of all fourteen variables in our analyses. We predicted higher multiCV values for the family Heteromyidae than the Geomyidae and greater variation in multiCV across Heteromyidae genera based on qualitative observations of skulls and prior research (Hafner and Hafner 1988). We explored the relationship between size and multiCV using a phylogenetic generalized least squares regression (PGLS). We expected a statistically significant regression with increased variation associated with increased size, as a consequence of the unique enlarged bullae found in Dipodomyinae.

Allometry

We used PGLS to analyze allometry within Geomyoidea. We analyzed allometry at the family level to determine the possible covariance of size and shape using caper 1.0.1 (Orme, 2018) and code modified from Calede and Brown (2021). Allometric analyses were run separately for the two families. The natural log of the geometric mean was used as the x-axis variable; PC values were used for the y-axis. The PGLS was run on all 100 trees to account for uncertainties in branch lengths. For the family Heteromyidae, we also ran follow-up analyses for the subfamily Dipodomyinae and non-dipodomyine heteromyids in light of the pattern recovered in the family-wide analysis.

RESULTS

Size

The results of our analysis of the log transformation of the geometric means in Geomyidae show a dispersion of mean values between 0.9 and 1.3 (Fig. 1). The mean values of the log transformed geometric means in Heteromyidae range between 0.7 and 1.1 (Fig. 1). Overall, there is greater size variation in geomyid species than heteromyid species. Within Geomyidae, *Geomys*

and *Thomomys* have the largest range of values. Within heteromyids, *Perognathus longimembris, Heteromys gaumeri, and Chaetodipus hispidus* have the largest range of values. Cranial size is significantly different among species within both geomyids (ANOVA: $F=175.8$, $p<0.001$) and heteromyids (ANOVA: $F=545.8$, $p<0.001$); it is also significantly different among genera (ANOVAs: $F=218.2$, $p<0.001$ and $F=699.7$, $p<0.001$ respectively). Among geomyids, only three pairs of genera are not significantly different in size. Those include *Orthogeomys* and *Heterogeomys*, *Zygogeomys* and *Cratogeomys*, as well as *Thomomys* and *Pappogeomys*. Within Heteromyidae, only *Microdipodops* and *Chaetodipus* are not significantly different from one another.

Post-hoc comparisons using Tukey tests show significant differences in over 82% of the taxon pairs within Geomyidae (Appendix 2) and 90% of taxon pairs within Heteromyidae (Appendix 3). However, there are several species that are not significantly different from congeneric species. Thus, *Cratogeomys merriami* and *C. fumosus* are not significantly different from one another; neither are *Heterogeomys hispidus* and *H. heterodus*. Within *Geomys, G. bursarius* is not significantly different from *G. personatus* or *G. pinetis; G. personatus* is not significantly different in size from *G. pinetis* and *G. arenarius*. Within the genus *Thomomys*, there is no significant difference in size between *T. umbrinus* and *T. bottae* or *T. talpoides*. *Chaetodipus californicus* is not significantly different from *C. penicillatus*. *Perognathus longimembris* is not significantly different in size from either *P. flavescens* or *P. flavus.* The two species of *Microdipodops* cannot be differentiated by size. Within *Dipodomys*, *D. ingens* is not significantly different from *D. deserti* or *D. spectabilis*; *D. ordii* and *D. heermanni* are also not significantly different. Four pairwise differences can be identified within *Heteromys*; these include *H. desmarestianus*/*H. anomalus*, *H. gaumeri*/*H. anomalus*, *H. irroratus*/*H. gaumeri*, and *H. pictus*/*H. irroratus*.

Phylomorphospace and family-level differences

The two families occupy distinct regions of the morphospace (MANOVA: $F=10.64$, $p<0.001$; Fig. 2). Interfamily differences are concentrated along PC1 (ANOVA: $F=787.8$, $p<0.001$). Geomyids occupy the left side of the morphospace (negative PC1 scores), which corresponds to broad zygomatic arches (MAW), large mandible length (MANL), long diastemata (LD and

LDL), deep mandibles (DMND), and deep maxillary regions (DM2). Heteromyids are restricted to the right side of the morphospace (positive PC1 scores). They are characterized by wide palates (PW) and long skulls (GCL). There is a greater disparity among Heteromyidae than Geomyidae, particularly along PC2. Heteromyids span the entire range of the morphospace along this axis with the genus *Heteromys* displaying the lowest PC2 scores (associated with large rostral width [RW] and narrow skulls [low MAW and GCW]) whereas *Dipodomys* and *Microdipodops* occupy the positive end of PC2 (associated with broad and deep skulls but very narrow rostra). *Chaetodipus* and *Perognathus* occupy the middle of the axis (-1<PC2 scores<1). The most recent common ancestor of Heteromyidae is most similar in morphology to *Chaetodipus*. The most recent common ancestor of the Geomyoidea is itself very similar in morphology to the common ancestor of Heteromyidae. The most recent common ancestor of Geomyidae is most similar in morphology to *Thomomys*.

The CVA results show a distinct difference between Geomyidae and Heteromyidae (Fig. 3a). Geomyidae have negative, much lower CVA scores than heteromyids. Both families are 100% correctly identified by the classification phase of the analysis.

Genus-level variation

The principal component analysis of the cranial measurements of geomyid specimens shows distinct morphospace occupation for the seven genera (MANOVA: $F= 21.85$, $p<0.001$). Only two axes are significant; they explain over 34% of the variance (Fig. 4a). PC1 is positively correlated with IMW, GCD, and DMND as well as negatively correlated with LD, LDL, and MRD. PC2 is positively correlated with GCW and RW; it is negatively correlated with PW. *Orthogeomys* and *Geomys* occupy the left side of the morphospace (negative PC1 scores). *Pappogeomys* occupy the right side of the graph (positive PC1 scores). *Heterogeomys*, *Zygogeomys* and *Cratogeomys* occupy the center of the graph; *Thomomys* range across most of PC1. *Thomomys* and *Geomys* cluster at the negative end of PC2 whereas *Zygogeomys*, *Heterogeomys*, and *Cratogeomys* cluster at the positive end of PC2.

The principal component analysis of the cranial measurements of heteromyid specimens shows distinct morphospace occupation for the seven genera (MANOVA: $F= 184.4$, $p<0.001$). Only two axes are significant; they explain over 53% of the variance (Fig. 4b). PC1 is positively

correlated with MANL, RW, LD, and NL as well as negatively correlated with GCW, GCD, and PW. PC2 is positively correlated with GCL and IMW as well as negatively correlated with MAW, LDL, and DMND. *Microdipodops* occupy the left side of the graph (most negative PC1 scores); *Heteromys* and *Chaetodipus* occupy the right side of the graph (positive PC1scores). *Dipodomys* and *Perognathus* occupy the center of the morphospace.

The canonical variate analysis for the family Geomyidae shows distinctions between genera (Fig. 3b). CV1 represents 60.9% of the variance whereas CV2 represents 17.6% of it. Positive CV1 scores correspond to large GCL, MAW, and GCD values whereas negative CV1 scores correspond to large RW, GCW, and DM2 values. Positive CV2 scores largely represent large MANL and DM2 values; negative CV2 scores represent large LDL, GCW, GCD, and MAW values. *Cratogeomys* occupy the uppermost right corner of the morphospace (positive PC1 and PC2 values). *Heterogeomys* and *Orthogeomys* occupy the uppermost left corner of the morphospace (negative PC1 values and positive PC2 values). *Thomomys* occupy the lower left corner (negative PC1 and PC2 values); *Pappogeomys*, *Zygogeomys*, and *Geomys* occupy the lower right corner of the morphospace (positive PC1 and negative PC2 values).

The canonical variate analysis shows distinction between heteromyid genera (Fig. 3c). CV1 represents 74.5% of the variation whereas CV2 represents 17.3% of the variation. Positive CV1 scores are associated with large GCW and MAW values. Negative CV1 scores correspond to large MANL values. Positive CV2 scores correspond to large GCL values whereas negative CV2 scores correspond to large MAW values. *Heteromys* occupy the left-most side of the morphospace (negative CV1 scores, CV2 scores ~ 0); *Perognathus* and *Chaetodipus* also have CV2 scores distributed around zero, but more positive CV1 values than *Heteromys*. *Microdipodops* occupies the upper right corner of the morphospace (positive CV1 and CV2 scores). *Dipodomys* occupies the lower right corner (positive CV1 scores and negative CV2 scores).Geomyid genera have lower accurate classification rates than heteromyid genera. Within Geomyidae, specimens of *Zygogeomys* are correctly identified most accurately (90%). *Thomomys* specimens are accurately identified at a slightly lower rate of 84.4%. *Cratogeomys* and *Heterogeomys* have accurate classification rates around 75%. *Orthogeomys* and *Geomys* have accurate classification rates above 60%. *Pappogeomys* has the lowest accurate rate of classification (40%). Within Heteromyidae, all genera are accurately identified at rates at or above 80%. Both *Microdipodops* and *Dipodomys* are correctly identified 100% of the time.

Heteromys is accurately identified 92% of the time. Both perognathine genera have accurate classification rates above 80%.

Species-level variation

Cratogeomys

The PCA of the data for the genus *Cratogeomys* (Fig. 5a) show significant differences among species (MANOVA: $F=24.9$, $p<0.001$). The first two axes of the PCA account for 36% of the variance in the dataset (PC1: 21.5%, PC2: 14.5%). The PC1 scores of the three species are significantly different (ANOVA: $F= 9.75$, $p<0.001$). PC1 is positively correlated with MAW and negatively correlated with DM2, MRD, GCD, and PW. *Cratogeomys fumosus* occupies the positive end of PC1. A post-hoc Tukey test demonstrates that *C. fumosus* is significantly different from the other two species in PC1 scores (ANOVA: $F=24.5$, $p<0.001$, both post-hoc tests $p<0.001$). PC2 is positively correlated with NL and negatively correlated with PW and IMW. *Cratogeomys merriami* has higher PC2 scores than the other two species (post-hoc Tukey tests: $p<0.001$ for both comparisons).

CV1 explains 72.9% of the variation; CV2 27.1% (Fig. 7a). Positive CV1 scores correspond to larger GCW and IMW whereas negative CV1 scores correspond to large DM2 and LDL values. Positive CV2 scores correspond to large DM2 values; negative CV2 scores correspond to large LDL values. *Cratogeomys castanops* has low CV1 and CV2 scores; *C. fumosus* has low CV2 but high CV1 scores; specimens of *C. merriami* have high CV1 scores and intermediate CV2 scores. *Cratogeomys castanops* specimens are identified correctly by the *a posteriori* analysis 92% of the time, *Cratogeomys fumosus* specimens 84% of the time, and *Cratogeomys merriami* specimens 79% of the time.

Geomys

The PCA of the cranial measurements of *Geomys* shows distinct morphospace occupation for the four species (Fig. 5b; MANOVA: $F= 16.7$, $p<0.001$). Three axes are significant; they explain over 65% of the variance in the dataset (PC1: 34.1%, PC2: 20%). The PC1 scores of the four species are significantly different (ANOVA: $F= 25.29$, $p<0.001$). PC1 is positively correlated with LDL and LD, but negatively correlated with GCD, IMW, and DM2. *Geomys pinetis* and *G.*

bursarius occupy the positive end of PC1 whereas *G. personatus* and *G. arenarius* occupy the negative end of the axis. The species within each of these two clusters do not differ significantly from one another but species across clusters do (all p values <0.001). PC2 is positively correlated with LD and negatively correlated with PW. The PC2 scores of the *Geomys* species studied are significantly different (ANOVA: $F=13.82$, $p<0.001$). *Geomys personatus* displays positive PC2 scores whereas *G. arenarius* displays negative PC2 scores. All species differ significantly from one another in PC2 scores (all p values <0.03) except *G. pinetis* and *G. bursarius*.
CV1 accounts for 55.7% of the variation (Fig 7b). Positive CV1 scores correspond to larger GCL and LD values whereas negative CV1 scores correspond to large MAW measurements. CV2 accounts for 36.4% of the variation. Positive CV2 scores correspond to large MRD values; negative CV2 scores correspond to large MANL, GCW, and GCL values. *Geomys bursarius, Geomys arenarius,* and *Geomys pinetis* have high PC2 scores whereas *Geomys personatus* specimens have low CV2 scores. *Geomys arenarius* specimens are correctly identified *a posteriori* over 83% of the time; the classification rate for *G. bursarius* is somewhat lower at 72%. Classification rates for *G. personatus* and *G. pinetis* are the highest (>92%).

Heterogeomys

The PCA of the cranial measurements of *Heterogeomys* (Fig 5c) shows distinct morphospace occupation for the two species (MANOVA: $F= 4.4$, $p=0.002$). The first two axes of the PCA account for 42.2% of the variance in the dataset (PC1: 23.1%, PC2: 19.1%). The PC1 scores of the two species are significantly different (ANOVA: $F= 28.7$, $p<0.001$). PC1 is positively correlated with LDL, LD, DM2, and MANL, and negatively correlated with MAW, PW, and GCW. *Heterogeomys hispidus* occupies the negative end of the axis; *H. heterodus* occupies the positive end of PC1. PC2 is positively correlated with IMW and GCD; negatively correlated with MRD and NL.
Heterogeomys heterodus occupies the negative end of CV1; *H. hispidus* the positive end of the axis (Fig 7c). *Heterogeomys heterodus* specimens are classified correctly 88% of the time; *H. hispidus* almost 78% of the time.

Thomomys

The PCA of the cranial measurements of *Thomomys* (Fig. 5d) shows distinct morphospace occupation for the five species (MANOVA: F= 4.4, p<0.001). Four axes are significant; the first two explain over 41% of the variance in the dataset (PC1: 26.4%, PC2: 15.5%). The PC1 scores of the five species are significantly different (ANOVA: F=16.614, p<0.001). PC1 is positively correlated with IMW, RW, GCL, and GCD and negatively correlated with LD and LDL. *Thomomys monticola* and *T. talpoides* occupy the positive end of PC1 whereas *T. townsendii* and most specimens of *T. umbrinus* occupy the negative end of the axis. There is also a second cluster of *T. townsendii* with positive PC1 scores. All species of *Thomomys* differ significantly from one another except for the pair *T. umbrinus-T. townsendii* (p=0.97). PC2 is positively correlated with PW and negatively correlated with a number of morphological variables including MANL, LDL, and GCW. %). The PC2 scores of the five species are significantly different (ANOVA: F=28.73, p<0.001). *Thomomys monticola, T. townsendii,* and *T. talpoides* occupy the negative end of PC2 whereas *T. bottae* occupies the positive end. *Thomomys umbrinus* ranges widely along PC2. All species of *Thomomys* differ significantly from one another except for the pair *T. monticola-T. townsendii* (p=0.54) and the pair *T. umbrinus-T. talpoides* (p=0.59). CV1 accounts for 53.8% of the variation (Fig 7d). It is positively correlated with GCL and negatively correlated with MAW. *Thomomys monticola* and *T. talpoides* occupy the positive end of CV1; *T. bottae, T. umbrinus,* and *T. townsendii* the negative end of the axis. CV2 accounts for 26.3% of the variation. Positive CV2 scores correspond to large IMW and DM2 particularly; negative CV2 scores correspond to large RW and GCL values. *Thomomys townsendii* occupies the positive end of the axis whereas *T. bottae* occupies the negative end of PC2. The other species are intermediate in value along PC2. *Thomomys talpoides* specimens were accurately classified 70% of the time, *T. townsendii* over 78% of the time, and *T. monticola* over 93% of the time; *T. umbrinus* and *T. bottae* specimens are correctly identified 54% and 67% of the time respectively.

Chaetodipus

The PCA of the data for the genus *Chaetodipus* (Fig 6a) shows significant differences among the five species (MANOVA: F=8.8, p<0.001). Four axes are significant; the first two account for nearly 39% of the variance in the dataset (PC1: 22.7%, PC2: 16%). PC1 is positively correlated with DMND and LDL; it is negatively correlated with IMW, GCL. GCW, PW, and GCD.

Chaetodipus intermedius and *C. californicus* occupy the negative end of PC1; *C. hispidus, C. baileyi,* and *C. penicillatus* the positive end of the axis (Fig 6a). The PC1 scores are significantly different among all species (ANOVA: $F=29.8$, $p<0.001$; post-hoc Tukey tests: $p<0.05$) except for the pairs *Chaetodipus penicillatus* and *C. baileyi* ($p= 0.73$), and *C. intermedius* and *C. californicus* ($p=0.44$). PC2 is positively correlated with NL, MNAL, LD, MAW, and GCL; it is negatively correlated with RW, DM2, PW, and GCD. All species range widely along PC2. None of them differ statistically (ANOVA PC2: $F=2.11$, $p=0.19$).

The first two axes of the CVA represent over 65% of the variation (Fig. 8a). Positive CV1 scores correspond to larger IMW values and negative CV1 scores correspond to large GCD values. *Chaetodipus californicus* and *C. intermedius* occupy the positive end of the axis; *C. baileyi* and *C. hispidus* the negative end. Positive CV2 scores correspond to a larger MANL, MAW, and MRD; negative CV2 scores correspond to larger GCL and GCW values. *Chaetodipus baileyi* and *C. intermedius* occupy the negative end of CV2; *C. californicus, C. penicillatus* and *C. hispidus* the positive end of the axis. *Chaetodipus baileyi* (55.6%) and *C. hispidus* (68.8%) specimens were classified correctly the least often. *Chaetodipus penicillatus* specimens were correctly identified 77.3% of the time; *Chaetodipus californicus* 71.4%. *Chaetodipus intermedius* specimens were accurately identified most often (81.3% accuracy).

Dipodomys

The PCA of the data for the genus *Dipodomys* (Fig 6b) show significant differences among species (MANOVA: $F=67.5$, $p<0.001$). Two axes are significant; they explain over 41% of the variance in the dataset (PC1: 24.9%, PC2: 16.6%). PC1 is positively correlated with DMND, LDL, MANL, and MANW; it is negatively correlated with PW and IMW. *Dipodomys spectabilis, D. heermanni,* and *D. ingens* occupy the positive end of PC1; *Dipodomys ordii, D. merriami,* and *D. deserti* the negative end of the axis. The PC1 scores of the six species are significantly different (ANOVA: $F=67.5$, $p<0.001$). Dipodomys ingens, D. ordii, D. heermanni, D. merriami, and D. spectabilis are all statistically different along PC1 (all post-hoc Tukey tests: $p<0.001$), excluding the pair *D. ordii* and *D. merriami* ($p=0.99$). PC2 is positively correlated with GCL, GCW, and NL; it is negatively correlated with DM2. *Dipodomys deserti* occupies the positive end of PC2; all other species cluster on the lower end of the axis. *Dipodomys* species differ significantly in PC2 scores (ANOVA: $F=41.02$, $p<0.001$). *Dipodomys deserti* differs

significantly from all other species (all post-hoc Tukey tests: $p<0.001$). Additionally, *D. ingens* significantly differs from *D. heermanni* ($p=0.03$). All other taxon pairs are not significantly different ($p>0.05$).

The first two axes of the CVA (Fig 8b) represent 83% of the variation (CV1: 54.3%, CV2: 28.9%). Positive CV1 scores correspond to larger GCL and MRD values; negative CV1 scores correspond to large MAW and MANL values. *Dipodomys ordii* and *D. merriami* occupy the positive end of PC1; *D. spectabilis, D. ingens,* and *D. heermanni* the negative end; *D. deserti* the middle of the axis. Positive CV2 scores correspond to a larger MANL in particular. Negative CV2 scores correspond to a larger GCW. *Dipodomys deserti* occupies the negative end of PC2; all other species the positive end. *Dipodomys deserti* specimens were accurately classified 100% of the time. Specimens of *D. heermanni* were correctly identified over 91% of the time. *Dipodomys spectabilis* and *D. ingens* were accurately classified about 77% of the time. *Dipodomys merriami* and *D. ordii* specimens were correctly identified 71% and 67% of the time respectively.

Perognathus

The PCA of the data for the genus *Perognathus* (Fig 6c) shows significant differences among species (MANOVA: $F=7.6$, $p<0.001$). Four axes are significant; the first two represent 38% of the variance in the dataset (PC1: 21.78%, PC2: 16.4%). PC1 is positively correlated with GCL, MANL, LD, and a number of other variables; it is negatively correlated with DMND. *Perognathus longimembris* and *P. parvus* occupy the positive end of PC1; *P. flavus* and *P. flavescens* the negative end of the axis. *Perognathus* species differ significantly in PC1 scores (ANOVA: $F=27.01$, $p<0.001$). *Perognathus flavescens* is significantly different in PC1 scores from all other species (post-hoc Tukey tests: $p<0.001$); all other comparison pairs are not significantly different (post-hoc Tukey tests: $p>0.12$). PC2 is positively correlated with GCD and GCW; it is negatively correlated with RW and MRD. *Perognathus flavus* and *P. flavescens* occupy the positive end of PC2; *P. longimembris* and *P. parvus* range widely along the axis. Only *P. parvus* is significantly different from other species along PC2, specifically *P. flavus* and *P. flavescens* (ANOVA: $F=6.36$, $p<0.001$; post-hoc Tukey tests: $p<0.03$).

The first two axes of the CVA represent 92% of the variation (PC1: 49.4%, PC2: 43.3%). Positive CV1 scores correspond to larger IMW and LD values; negative CV1 scores correspond

to a large GCD. *Perognathus parvus* occupies the center of CV1, *P. flavus* and *P. longimembris* the positive end, and *P. flavescens* the negative end. Positive CV2 scores correspond to a larger NL, GCD, and MANL; negative CV2 scores correspond to a large MAW. *Perognathus parvus* occupies the positive end of CV2. *Perognathus flavus, P. longimembris,* and *P. flavescens occupy* the negative end of the axis. *Perognathus flavus* and *P. longimembris* specimens were the most poorly identified (under 60% of the time). *Perognathus parvus* specimens were identified correctly 63% of the time. All specimens of *P. flavescens* were accurately classified.

Heteromys

The PCA of the data for the genus *Heteromys* (Fig 6d) shows significant differences among species (MANOVA: $F=17.8$, $p<0.001$). Two axes are significant; they account for almost 47% of the variance in the dataset (PC1: 28.8%, PC2: 17.8%). PC1 is positively correlated with GCW, GCD, and several other variables; it is negatively correlated with MRD, MANL, LD, and LDL. *Heteromys pictus, H. gaumeri* and *H. irroratus* occupy the positive end of the axis; *H. anomalus* and *H. desmarestianus* the negative end. The PC1 scores of the five species are significantly different (ANOVA: $F=27.5$, $p<0.001$). *H. pictus* and *H. irroratus* are not significantly different along PC1 (post-hoc Tukey tests: $p=0.06$), *H. irroratus* and *H. gaumeri* are not significantly different (post-hoc Tukey tests: $p=1.00$), and *H. anomalus* and *H. desmarestianus* are not significantly different (post-hoc Tukey tests: $p=0.70$). PC2 is positively correlated with DMND and negatively correlated with PW. *Heteromys gaumeri, H. desmarestianus,* and *H. anomalus* occupy the positive end of PC2; *H. pictus* and *H. irroratus* the negative end of the axis. The species are significantly different along PC2 (ANOVA: $F=11.3$, $p<0.001$). *Heteromys gaumeri* has significantly higher PC2 scores than all other species (post-hoc Tukey tests: $p<0.001$ for all comparisons) except *H. desmarestianus*. *Heteromys pictus* has significantly lower PC2 scores than *H. desmarestianus* (post-hoc Tukey test: $p=0.007$).

CV1 represents 70.6% of the variation (Fig 8d). Positive scores correspond to larger MAW and GCW values; negative scores correspond to a large MRD. *Heteromys gaumeri, H. pictus,* and *H. irroratus* occupy the positive end of CV1; *H. anomalus* and *H. desmarestianus* the negative end of the axis. CV2 represents 15.1% of the variation. Positive scores correspond to a larger GCW, MANL, and MRD; negative scores correspond to a larger GCL. *Heteromys pictus, H. anomalus,* and *H. irroratus* occupy the positive end of the axis; *H. desmarestianus* and *H. gaumeri* the

negative end. *Heteromys gaumeri* specimens were identified correctly most often, at 93.8%. *Heteromys irroratus* specimens were identified correctly the least, at 62%. *Heteromys pictus* specimens were accurately identified 68.4% of the time; *H. anomalus* 87.5%; *H. desmarestianus* 82.4%.

Microdipodops

The PCA of the data for *Microdipodops* (Fig 6e) shows significant differences among species (MANOVA: $F=13.96$, $p<0.001$). Two PCA axes are significant; they account for 44% of the variance in the dataset (PC1: 26%, PC2: 17.7%). PC1 is positively correlated with DMND and LDL; it is negatively correlated with GCL, among other variables. The two species are not significantly different along PC1 (ANOVA: $F=1.36$, $p=0.25$). PC2 is positively correlated with MRD and NL; it is negatively correlated with GCD and several other variables. *Microdipodops pallidus* has higher PC2 scores (ANOVA: $F=25.12$, $p<0.001$).

The CVA retains a single significant axis. Positive CV1 scores correspond to *M. pallidu*s and negative CV1 scores to *M. megacephalus (*Fig 8e*). Microdipodops megacephalus* specimens are accurately classified over 83% of the time, *M. pallidus* over 90% of the time.

Multivariate Coefficient of Variation

Both families display multivariate coefficient of variation values below 10 % (Fig. 9a). The multivariate coefficient of variation (multiCV) is lower for the family Geomyidae than for Heteromyidae. The genus-level multiCV values show that *Geomys* and *Thomomys* display greater variation in cranial morphology than all heteromyid genera. Among geomyids, *Thomomys* has the highest multiCV (multiCV = 6.06%); *Heterogeomys* displays the lowest level of variation (multiCV = 4.73%). Within Heteromyidae, *Chaetodipus* displays the highest level of variation (multiCV = 4.52%); *Dipodomys* displays the lowest level of variation (multiCV = 3.58%). The mean multiCV for the family Geomyidae is 4.46%; the median 4.33%. The mean multiCV for the family Heteromyidae is 3.59%; the median 3.58%. The standard deviation in multiCV is slightly higher within Heteromyidae (0.74) than within Geomyidae (0.71). The species-level multiCV values of geomyids reveal a range of variation within all genera, except *Cratogeomys*. *Geomys personatus* displays the lowest amount of variation (multiCV = 3.4%;

Fig. 9b). *Thomomys bottae* and *T. umbrinus* display the highest amount of variation (multiCV ~5.7%). The species-level multiCV for heteromyids reveals that all species of *Dipodomys* show relatively low amounts of variation (Fig. 9c); high levels of variation are present across all other genera. *Dipodomys merriami* displays the lowest amount of variation (multiCV = 2.24%). *Chaetodipus baileyi* and *Perognathus longimembris* display the largest amount of variation (multiCV~4.9%). There is no significant relationship between taxon size and multiCV (PGLS: p=0.617).

Allometry

The phylogenetic generalized least squared analyses show distinct regression patterns across families. The regression of shape on size in Geomyidae is negative for PC1 (R^2= 0.24, p=0.044; Fig. 10a) and positive for PC2 (R^2=0.67, p=0; Fig. 10b). Within Heteromyidae, there is a positive relationship between size and shape as indicated by PC1 (R^2=0.73, p=0.006; Fig. 10c) and a negative relationship between size and PC2 (R^2=0.59, p=0; Fig. 10d). Within the family Heteromyidae, the subfamily Dipodomyinae displays a different pattern of allometry (involving PC1) compared to perognathines and heteromyines (Fig. 10c). When the two groups are considered independently, the allometric relationship is much stronger (Figs. 10e-f). In both dipodomyines (R^2=0.92, p=0) and non-dipodomyines (R^2=0.88, p=0), the relationship between size and shape is positive.

DISCUSSION

Our results show that many genera and species of Heteromyidae and Geomyidae can be distinguished by their size. The greater size variation we observe in Geomyidae compared to Heteromyidae is consistent with the large variation in size across pocket gophers observed by Hafner et al. (2014) and Hafner and Hafner (1988). The higher prevalence of sexual size dimorphism in geomyids compared to heteromyids (Calede and Brown 2021) also likely contributes to the greater size variation in Geomyidae, although there is no evidence that the species with the largest size variation in our analyses are also those with significant sexual size dimorphism in Calede and Brown (2021). The lack of size difference between *Heterogeomys* and *Orthogeomys* we recover is consistent with prior analyses of the morphology of these taxa

(Spradling et al. 2016). Our finding that species of *Perognathus* are mostly smaller than those of the sister genus *Chaetodipus* is consistent with previous research (Wyatt et al. 2021); the exact rank order of species and statistical differences differ somewhat between our analyses based on cranial measurements and those of Wyatt et al. (2021) based on toothrow length. Future analyses building upon prior work on geomyoid body mass (Hopkins 2008) will be necessary to determine the best approach to quantifying size in pocket mice, and other geomyoids. Our results show that *Heterogeomys heterodus* is larger than *Heterogeomys hispidus*, but not significantly so, a pattern that is consistent with the results of Spradling et al. (2016). Our data also show that many species of pocket mice can be differentiated using size. Wyatt et al. (2021) also found that size was an informative trait when identifying *Perognathus* and *Chaetodipus* specimens using dental material. Not surprisingly, our analyses demonstrate that the two geomyoid families can be reliably identified using cranial morphology. The adult specimens from the two families differ greatly in shape (Hafner and Hafner 1988). Our phylomorphospace displays a clear association between the evolution of geomyids and the increase in relative size of the lower jaw, and both diastemata as well as the deepening of the maxillary region and dentary. Our analyses also show that cranial morphology can be used to discriminate between geomyoid genera. Within Heteromyidae species from the same genus are similar in shape. On the contrary, within Geomyidae, many species of a single genus are scattered in morphospace and can closely resemble species from different genera. This pattern is evidence of widespread morphological convergence within Geomyidae. It is consistent with the suggestion by Hafner and Hafner (1988) that geomyids resemble one another in shape greatly. It also supports the observation of Wahlert (1985) of low levels of cranial divergence across Geomyidae. Wahlert (1985:17) suggested the "either recent diversification or long conservation of a successful design after a period of rapid evolution" was responsible for this pattern of morphological similarity. Our results demonstrate that the ancestral geomyid morphology is highly apomorphic and divergent from the ancestral heteromyid morphology. Further testing of the competing hypotheses of Wahlert (1985) will require the analysis of morphological evolution in a time-calibrated phylogenetic framework that includes fossil species. Heteromyidae range along the entire length of PC2 unlike the Geomyidae, which are restricted to the upper half of the PC2 scores. This increased disparity within Heteromyidae reflects greater variation in the relative width of the skull in the rostral, zygomatic, and basicranial regions. No extant geomyids occupies the region of the morphospace

that corresponds to skulls with narrow basicranial and zygomatic regions but broad rostra. However, this may be a product of extinction. If fossil gophers were added to the dataset, it is possible that the morphospace occupation by geomyids would greatly increase with some species occupying spaces in the lower half of the phylomorphospace. Although they do not have broad rostra, entoptychine gophers have narrower crania than their geomyine relatives (Calede and Rasmussen 2020). In fact, a prior ecomorphological analysis of cranial shape in select fossil geomyids show that extinct entoptychine and extant geomyine gophers can differ greatly in cranial shape (Calede et al. 2017). Some fossil species of extant geomyid genera, particularly *Geomys garbanii,* also display cranial morphologies that are divergent from those observed in congeners (Calede et al. 2017, White and Downs 1961).

Our phylomorphospace shows that the cranial shape of the most recent common ancestor of all geomyoids resembled that of the most recent common ancestor of heteromyids (as opposed to that of geomyids) and specifically was most similar to *Chaetodipus* and *Perognathus*. As such, our results partially support Hafner and Hafner (1988) who suggested that *Perognathus, Chaetodipus,* and *Heteromys* represent an approximation of the ancestral geomyoid condition. Pocket mice indeed represent a morphology similar to that of the most recent common ancestor of Geomyoidea. The future inclusion of fossil geomyoids into the framework we present here will enable a test of the accuracy of these ancestral character state constructions.

Although we do recover some similarities (mainly the relatively narrow rostrum of *Geomys* compared to *Thomomys*, *Cratogeomys*, and *Heterogeomys*), our results of the genus-level morphological variation within Geomyidae do not mirror the findings of Lessa and Stein (1992), who recovered a clear segregation between claw-digging and tooth-digging taxa based on a smaller (and slightly different) set of measurements. However, we do find morphological differences between dolichocephalic gophers (e.g., *Orthogeomys* and *Heterogeomys*) and so-called generalized ones (e.g., *Geomys*, *Pappogeomys*, *Cratogeomys castanops*, and *C. merriami*; Wilkins and Woods 1983). *Orthogeomys* and *Heterogeomys* overlap greatly in morphology in our analyses. This contrasts with the findings of Spradling et al. (2016) in which the two species occupy different regions of a morphospace that is restricted to the two genera. One of the main variables differing between the two taxa is the interorbital constriction, a variable we did not include in our analyses.

Our CVAs show that many geomyid genera and all heteromyid genera can accurately (>75%) be identified using cranial measurements. However, *Orthogeomys*, *Geomys,* and *Pappogeomys* are more difficult to identify from cranial measurements than other geomyoid genera. The lower rate of accurate classification for *Orthogeomys* specimens is a consequence of their similarity with *Heterogeomys* in the absence of data on interorbital constriction. The low rates for *Pappogeomys* and *Geomys* are associated with the convergence between these two genera, particularly between *P. bulleri* and *G. personatus*. *Pappogeomys* has historically been difficult to delineate systematically in the absence of molecular data (Hafner et al. 2009). Tooth shape appears to be more informative than cranial morphology to identify geomyid specimens to the genus level for *Geomys, Orthogeomys, Heterogeomys*, and *Thomomys* but not for *Cratogeomys* (Calede and Glusman, 2017). Similarly, tooth shape performs better than cranial morphology in distinguishing between perognathine genera (Wyatt et al. 2021).

Our analyses demonstrate that geomyid species can be reliably identified using cranial morphology. Indeed, major morphological differences among species within each genus can be observed (Fig. 5) and informs taxonomic identification (Fig. 7). Cranial morphology is highly informative of taxonomic identity within *Cratogeomys.* This result is consistent with prior analyses of skull shape in the genus (Hafner et al. 2005, 2008). All *Cratogeomys* specimens can be identified accurately over 79% of the time. These rates of classification are overall higher than those found using dental morphology (Calede and Glusman, 2017) suggesting that cranial morphology is more helpful than tooth morphology in identifying *Cratogeomys* species. Within *Geomys, G. arenarius* overlaps in morphology with both G. *bursarius* and *G. pinetis.* There is one outlier specimen of *G. personatus* within the morphospace occupied by *G. arenarius.* *Geomys bursarius* also overlaps with *G. pinetis.* *Geomys penicillatus* only overlaps with *G. pinetis.* This pattern of overlap is similar to the one described by Mauk et al. (1999), although *G. pinetis* was not included in their analyses. The overlap involving *G. bursarius* explains the lower correct identification percentage for this taxon (72.2%) compared to other *Geomys* species. Other species of the genus can reliably be identified using cranial measurements. The high rates of accurate classification for *G. pinetis* using cranial measurements mirror the results of an analysis using tooth shape (Calede and Glusman, 2017). It appears that *G, arenarius* is in fact more easily identified using cranial measurements than tooth shape. Within *Heterogeomys,* there is little overlap in morphology between the two species. Although specimens of *H. hispidus* are

accurately classified more often, both species can be reliably identified using skull measurements. Spradling et al. (2016) found *H. heterodus* to be more often correctly identified than *H. hispidus* with a different set of craniodental measurements, but Calede and Glusman (2017) found similar rates of correct classification using dental morphology. Our findings are consistent with the validity of cranial measurements as a taxonomic tool in this genus. Within *Thomomys*, overlaps in morphology of *T. bottae* with essentially all other species lead to a low rate of correct classification for the taxon (67.3%); this same species was also difficult to differentiate form others using dental morphology (Calede and Glusman, 2017). The wide ecomorphospace occupation of *T. umbrinus* with two clusters of specimens, leads to the lowest rate of accurate identification for this species. Prior analyses of the morphospace occupation of *T. umbrinus* specimens has showed the presence of morphologically divergent subspecies (Calede and Brown, 2021) and a detailed analysis of the species demonstrates the presence of morphological variance across populations and subspecies of the taxon (Mathis et al., 2014). Future analyses including large samples of subspecies of *T. umbrinus* as well as other sympatric and parapatric *Thomomys* species will be informative of the potential for cranial morphology to help resolve morphological evolution and the identification of uncertain specimens in museums. The low morphological disparity of *T. monticola* and *T. townsendii* yield the best rates of classification for the genus; these two species can reliably be identified using cranial measurements, better than using tooth morphology (Calede and Glusman, 2017).

The cranial morphology of heteromyids within genera (Fig. 6) can be used to inform specimen taxonomic identification (Fig. 8), although not as well as in geomyids (54% *versus* 59% of species 75% accurately identified or better). Within *Chaetodipus*, there is a lot of overlap in morphospace among species. Variation within *C. intermedius* is driven largely by rostral width, greater cranial length, mandible length, greater cranial depth, and mandible length. These are all very important variables in the analysis of intraspecific variability of cranial measurements (Weckerly and Best 1985). Our results suggest that these variables are also important in driving the intraspecific variation within *C. hispidus* and *C. penicillatus*. The rates of classification for the species are low in three of the five taxa (*C. hispidus*, *C. baileyi*, and *C. californicus*), but this is a consequence of single outliers in each species that suggest that larger sample sizes for all taxa, that help capture more of the morphological variation across populations, would help improve these classification rates. *Chaetodipus intermedius* and *C. penicillatus* can be reliably

identified from cranial measurements. Interestingly, *C. intermedius* is also one of the species of the genus with the most distinctive dental morphology (Wyatt et al. 2021). *Chaetodipus penicillatus* is not and *C. hispidus* is however, suggesting that there is not a match between morphological divergence in the dentition and the cranium. Within *Dipodomys*, there is a lot of overlap in morphospace among clusters of species. *Dipodomys deserti* is distinct in morphology from all other species of the genus, largely because of a larger cranium (including length and width); it can be reliably identified from cranial measurements. *Dipodomys merriami* and *D. ordii* as well as *D. ingens*, *D. heermanni*, and *D. spectabilis* are very similar in morphology. As a consequence, the rates of classification are low for four of these six taxa (*D. merriami, D. ingens, D. ordii, and D. spectabilis*). Within *Perognathus*, there is a lot of overlap in morphospace between *P. longimembris* and *P. flavus*; it is largely driven by similarities in rostral and maxillary morphology. These variables are also important in driving the intraspecific variation within *P. longimembris* and *P. flavus*. Prior analyses of the variation within *P. parvus* failed to recover particular morphological variables as indicative of populations (Riddle et al. 2014). The rates of classification are low in three of the four taxa (*P. flavus, P. longimembris,* and *P. parvus*), which overlap greatly in morphospace, and very high for *P. flavescens*. A similar pattern of morphological overlap and high misidentification rates was recovered in the tooth shape analysis of Wyatt et al. (2021). Within *Heteromys*, two species display important intraspecific variation (*H. pictus* and *H. irroratus*) and overlap one another heavily in morphospace; they show low rates of classification as a consequence. *Heteromys desmarestianus, H. gaumeri,* and *H. anomalus* however can reliably be identified from cranial measurements. There are two clusters of specimens within *H. desmarestianus*, which suggests that future analyses of the intraspecific variation within this species may reveal interesting taxonomic information. Prior studies of the variation in cranial shape within *Heteromys* has contributed to the identification of several species (Anderson and Gutierrez 2009, Anderson and Timm 2006; Anderson and Jarrín-V 2002). Within *Microdipodops*, the separation in morphospace between the two species is a consequence of the longer and deeper rostrum of *M. pallidus* and the longer diastemata as well as deeper maxilla and basicranium of *M. megacephalus*. *Microdipodops pallidus* specimens are identified correctly more often than *M. merriami* specimens, but the rates of classification for both species are high.

Our analysis of morphological disparity using the multivariate coefficient of variation (multiCV) shows that Heteromyidae displays greater variation than Geomyidae. This is consistent with the morphospace occupation observed in the phylomorphospace and prior observations (Hafner and Hafner 1988). At the genus level, the opposite pattern is true. The multiCVs of geomyid genera tend to be larger than those of heteromyid genera. Unlike for dental morphology (Calede and Glusman 2017), *Thomomys* does not display lower disparity in cranial morphology than Geomyini genera. We do not find a correlation between size and multiCV. The range of squared multiCVs we recover across geomyoid species is narrower than that found by Soulé and Zegers (1996) across populations of *T. bottae*. None of the species we studied reaches the highest level of morphological variation observed by Soulé and Zegers (1996). Nonetheless, *T. bottae* displays the second highest level of variation of any geomyid (or even geomyoid) species we studied, after *T. umbrinus*. On the contrary, *T. monticola* and *T. townsendii* display very low levels of multivariate variation. The genus *Thomomys* shows the highest range of multiCV values among species of any geomyoid genus; *Cratogeomys* shows the lowest level. There are a few outlier species that display unexpected levels of variation for the genus. *Geomys personatus* has a very low multiCV compared to congenerics; the same is true for *Perognathus flavescens.* Future analyses exploring the correlation between morphological and genetic variation in geomyoids (following Soulé and Zegers 1996) may shed new lights on the taxonomy of particularly with regards to cryptic taxonomy in geographically widespread highly phenotypically variable taxa and the effects of possible bottlenecks on phenotype in species that are little variable.
Heteromyidae and Geomyidae display regression trends that are opposites of each other for both axes of variation. Geomyidae show negative allometry for PC1 and positive allometry for PC2; Heteromyidae show positive allometry for PC1 and negative allometry for PC2. Notable morphological variables that scale with negative allometry within Geomyidae include IMW, GCD, DMND, PW, and GCL whereas the variables that scale with positive allometry include LDL, LD, MRD, and GCW. Within Heteromyidae, the morphological variables that scale with negative allometry include GCD, GCW, PW, MAW, and LDL whereas the variables that scale with positive allometry include MANL, GCL, RW, LD, NL, and MRD. Both families share common allometric patterns for four morphological variables (PW, GCD, LD, and MRD), which may be inherited from the common ancestor for the two families. Interestingly, two of the variables associated with the extreme inflation of the bullae of dipodomyines (GCD and GCW,

but not GCL) scale with negative allometry. The allometric difference in slope between dipodomyines and non-dipodomyines supports an important role of heterochrony in the evolution of the morphology of the subfamily (Hafner and Hafner 1988). The exact importance of heterochrony in driving cranial evolution within Heteromyidae should be further explored by incorporating fossil dipodomyines in the framework we present herein (Voorhies 1975, Wood 1935). This will enable the specific test of the hypothesis that Dipodomyinae are paedomorphic and geomyids are hypermorphic as suggested by Hafner and Hafner (1988). Within Geomyidae, *Thomomys* displays an interesting pattern whereby the relative positions of *T. monticola, T. talpoides, T. bottae,* and *T. townsendii* in the allometric analysis mirror those recovered by Marcy et al. (2016) in their analysis of the cranium of the genus, particularly the analysis of the ventral view of the skull. Our analyses demonstrate differences in cranial morphology among geomyoid taxa at the family, genus, and species levels. These differences are taxonomically informative and many geomyoid taxa can be reliably identified using cranial measurements. This approach is more effective in Heteromyidae than Geomyidae. That is a consequence of a lower cranial variation within Heteromyid genera and species than in geomyids as well as a greater divergence among genera. The skull shape of geomyids is highly convergent between species and genera. The framework presented herein should be used to investigate the disparity of cranial morphologies observed in the geomyoid fossil record. In fact, fossils will enable formal tests of a number of hypotheses regarding cranial evolution in Geomyoidea combined with analyses of rate of morphological evolution. Future work incorporating juvenile morphology will be important for rigorously testing developmental hypotheses.

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FIGURE CAPTIONS

Fig. 1: Results of the size comparison among species of geomyoids. (a) Size variation within Geomyidae. (b) Size variation within Heteromyidae. Abbreviations for species names are provided in Table 1.

Fig. 2: Phylomorphospace for the 39 Geomyoidea species studied. The family Geomyidae is clustered to the left of the morphospace; members of the family Heteromyidae are located on the right of the morphospace. Each point represents a species. Genera are color-coded. Species abbreviations are provided in Table 1. Abbreviations for cranial measurements are provided in Table 2.

Fig. 3: Canonical variate analyses at the family and genus-levels. (a) Family-level analysis. (b) Genus-level within family Geomyidae. (c) Genus-level within family Heteromyidae. Each point represents a specimen. Genera are color-coded. Abbreviations for cranial measurements are provided in Table 2.

Fig. 4: Principal Component Analyses showing shape variation within (a) Geomyidae, and (b) Heteromyidae. Each point represents a specimen. Genera are color-coded. Abbreviations for cranial measurements are provided in Table 2.

Fig. 5: Principal component analyses showing variation within genera for the family Geomyidae: (a) *Cratogeomys*, (b) *Geomys*, (c) *Heterogeomys*, and (d) *Thomomys*. Species are color-coded. Species abbreviations are provided in Table 1. Abbreviations for cranial measurements are provided in Table 2.

Fig. 6: Principal component analyses showing variation within genera for the family Heteromyidae: (a) *Chaetodipus*, (b) *Dipodomys*, (c) *Perognathus*, (d) *Heteromys*, and (e) *Microdipodops*. Species are color-coded. Species abbreviations are provided in Table 1. Abbreviations for cranial measurements are provided in Table 2.

Fig. 7: Canonical variate analyses at the species level. (a) *Cratogeomys*, (b) *Geomys*, (c) *Heterogeomys*, and (D) *Thomomys*. Each point represents a specimen. Species are color-coded. Species abbreviations are provided in Table 1. Abbreviations for cranial measurements are provided in Table 2.

Fig. 8: Canonical variate analyses at the species-level. (a) *Chaetodipus*, (b) *Dipodomys*, (c) *Perognathus*, (d) *Heteromys*, and (e) *Microdipodops*. Each point represents a specimen. Species are color-coded. Species abbreviations are provided in Table 1. Abbreviations for cranial measurements are provided in Table 2.

Fig. 9: Multivariate coefficients of variation for all taxonomic levels. (a) Family and genus-level coefficient values. (b) coefficients across species within Geomyidae. (c) coefficients across species within Heteromyidae. Genera are color-coded. Species abbreviations are provided in Table 1.

Fig. 10: Allometric relationships within Geomyoidea. (a) Allometric relationship between size and PC1 scores within Geomyidae. (b) Allometric relationship between size and PC2 scores within Geomyidae. (c) Allometric relationship between size and PC1 scores within Heteromyidae. (d) Allometric relationship between size and PC2 scores within Heteromyidae. (e) Allometric relationship between size and PC1 scores within Dipodomyinae. (e) Allometric

relationship between size and PC1 scores within non-dipodomyine heteromyids. p values are provided for each relationship. Each point represents a species. Genera are color-coded. Species abbreviations are provided in Table 1.

TABLES

Table 1: Sample of geomyoid rodents included in this study. Abbreviations: F: number of female specimens, M: number of male specimens, Abb. = Abbreviation used in the multivariate analysis.

Family	Subfamily	Genus	Species	F	M	Abb.
Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	10	14	Ccs
Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	9	10	Cfu
Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	12	12	Cme
Geomyidae	Geomyinae	*Geomys*	*arenarius*	9	9	Gar
Geomyidae	Geomyinae	*Geomys*	*bursarius*	8	10	Gbu
Geomyidae	Geomyinae	*Geomys*	*personatus*	8	8	Gpe
Geomyidae	Geomyinae	*Geomys*	*pinetis*	15	12	Gpi
Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	9	9	Hhe
Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	10	8	Hhi
Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	14	15	Ogr
Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	12	13	Pbu
Geomyidae	Geomyinae	*Thomomys*	*bottae*	26	23	Tbo
Geomyidae	Geomyinae	*Thomomys*	*monticola*	6	9	Tmo
Geomyidae	Geomyinae	*Thomomys*	*talpoides*	15	15	Tta
Geomyidae	Geomyinae	*Thomomys*	*townsendii*	12	11	Tto
Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	12	12	Tum
Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	10	10	Ztr
Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	9	10	Dde
Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	10	13	Dhe
Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	9	9	Din

Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	25	25	Dme
Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	20	20	Dor
Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	9	9	Dsp
Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	10	14	Mme
Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	10	11	Mpa
Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	8	8	Han
Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	9	8	Hde
Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	8	8	Hga
Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	11	10	Hir
Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	9	9	Hpi
Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	9	9	Cba
Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	9	12	Ccl
Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	8	8	Chi
Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	15	17	Cin
Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	11	11	Cpe
Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	8	8	Pfl
Heteromyidae	Perognathinae	*Perognathus*	*flavus*	8	9	Pfu
Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	11	12	Plo
Heteromyidae	Perognathinae	*Perognathus*	*parvus*	11	13	Ppa

Table 2: Description of the measurements used in the analyses.

Abb.	Description
GCL	Greatest cranium length from anterior edge of nasal to posterior edge of skull
NL	Nasal length
IMW	Intermaxillary width at M3
MAW	Maxillary arch width at widest point
GCD	Greatest cranium depth from dorsal edge of parietal to ventral edge of auditory bulla
GCW	Greatest cranium width across tympanic bullae
RW	Rostral width

Repository	Specimen	Family	Subfamily	Genus	Species	Sex
CM	75128	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F
CM	75129	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F
CM	75134	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F
CM	75137	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F

RD	Rostral depth
DM2	Depth of skull at M2 alveolus
PW	Palatine width between toothrows at P4
LD	Length of upper diastema
LDL	Length of lower diastema
DMND	Depth of dentary at m1
MANL	Mandibular length from anterior face of incisor to posterior edge of condyloid process

APPENDICES

Appendix 1: List of all specimens included in the study

CM	89198	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F
USNM	24496	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F
USNM	24501	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F
USNM	24504	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F
USNM	116535	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F
USNM	127356	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	F
CM	75130	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
CM	75136	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
CM	75138	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
CM	75140	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
CM	89197	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
USNM	24495	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
USNM	24503	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
USNM	50924	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
USNM	51048	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
USNM	58325	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
USNM	97171	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
USNM	108599	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
USNM	119071	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
USNM	246533	Geomyidae	Geomyinae	*Cratogeomys*	*castanops*	M
AMNH	26204	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	F
CM	55792	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	F
CM	55793	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	F
CM	55795	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	F
CM	55796	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	F
CM	55798	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	F
CM	55799	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	F
CM	55800	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	F
CM	55804	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	F
AMNH	26220	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
AMNH	26222	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
AMNH	26223	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
CM	55797	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
CM	55801	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
CM	55803	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
CM	55805	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
CM	55806	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
USNM	45207	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
USNM	33202	Geomyidae	Geomyinae	*Cratogeomys*	*fumosus*	M
USNM	5498	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	53494	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	54304	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F

USNM	54306	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	57963	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	57964	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	58167	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	58169	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	58170	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	58171	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	58172	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	50109	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	50110	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	53497	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	54307	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	54308	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	55346	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	55348	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	57970	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	58166	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	58168	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	54299	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	F
USNM	54300	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
USNM	55347	Geomyidae	Geomyinae	*Cratogeomys*	*merriami*	M
CM	90968	Geomyidae	Geomyinae	*Geomys*	*arenarius*	F
CM	90969	Geomyidae	Geomyinae	*Geomys*	*arenarius*	F
MVZ:Mamm	50460	Geomyidae	Geomyinae	*Geomys*	*arenarius*	F
USNM	18012	Geomyidae	Geomyinae	*Geomys*	*arenarius*	F
USNM	20314	Geomyidae	Geomyinae	*Geomys*	*arenarius*	F
USNM	20315	Geomyidae	Geomyinae	*Geomys*	*arenarius*	F
USNM	35599	Geomyidae	Geomyinae	*Geomys*	*arenarius*	F
USNM	58330	Geomyidae	Geomyinae	*Geomys*	*arenarius*	F
USNM	58332	Geomyidae	Geomyinae	*Geomys*	*arenarius*	F
AMNH	132030	Geomyidae	Geomyinae	*Geomys*	*arenarius*	M
CM	90965	Geomyidae	Geomyinae	*Geomys*	*arenarius*	M
CM	90966	Geomyidae	Geomyinae	*Geomys*	*arenarius*	M
CM	90967	Geomyidae	Geomyinae	*Geomys*	*arenarius*	M
CM	90970	Geomyidae	Geomyinae	*Geomys*	*arenarius*	M
CM	90971	Geomyidae	Geomyinae	*Geomys*	*arenarius*	M
CM	90972	Geomyidae	Geomyinae	*Geomys*	*arenarius*	M
OSUM	2494	Geomyidae	Geomyinae	*Geomys*	*arenarius*	M
USNM	18117	Geomyidae	Geomyinae	*Geomys*	*arenarius*	M
CM	4287	Geomyidae	Geomyinae	*Geomys*	*bursarius*	F
CM	4471	Geomyidae	Geomyinae	*Geomys*	*bursarius*	F
CM	4886	Geomyidae	Geomyinae	*Geomys*	*bursarius*	F

CMNH	21344	Geomyidae	Geomyinae	*Geomys*	*bursarius*	F
OSUM	6536	Geomyidae	Geomyinae	*Geomys*	*bursarius*	F
OSUM	6537	Geomyidae	Geomyinae	*Geomys*	*bursarius*	F
OSUM	6538	Geomyidae	Geomyinae	*Geomys*	*bursarius*	F
CM	4221	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
CM	48907	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
CM	48908	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
CMNH	21341	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
MVZ:Mamm	97911	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
USNM	179008	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
USNM	179400	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
USNM	180055	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
USNM	209776	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
USNM	243055	Geomyidae	Geomyinae	*Geomys*	*bursarius*	F
USNM	16677	Geomyidae	Geomyinae	*Geomys*	*bursarius*	M
CM	16220	Geomyidae	Geomyinae	*Geomys*	*personatus*	F
CM	48684	Geomyidae	Geomyinae	*Geomys*	*personatus*	F
CM	48687	Geomyidae	Geomyinae	*Geomys*	*personatus*	F
CM	48694	Geomyidae	Geomyinae	*Geomys*	*personatus*	F
CM	48695	Geomyidae	Geomyinae	*Geomys*	*personatus*	F
CM	48696	Geomyidae	Geomyinae	*Geomys*	*personatus*	F
CM	48990	Geomyidae	Geomyinae	*Geomys*	*personatus*	F
AMNH	2975	Geomyidae	Geomyinae	*Geomys*	*personatus*	M
CM	48685	Geomyidae	Geomyinae	*Geomys*	*personatus*	M
CM	48686	Geomyidae	Geomyinae	*Geomys*	*personatus*	M
CM	48690	Geomyidae	Geomyinae	*Geomys*	*personatus*	M
CM	48691	Geomyidae	Geomyinae	*Geomys*	*personatus*	M
CM	48692	Geomyidae	Geomyinae	*Geomys*	*personatus*	M
CM	48989	Geomyidae	Geomyinae	*Geomys*	*personatus*	M
CM	93665	Geomyidae	Geomyinae	*Geomys*	*personatus*	M
FMNH	51844	Geomyidae	Geomyinae	*Geomys*	*personatus*	F
CM	19478	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
CM	19480	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
CM	19483	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
CM	59734	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
CM	59735	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
UF	1114	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
UF	1243	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
UF	1244	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
UF	1935	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
UF	12329	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
UF	12331	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F

UF	13204	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
USNM	174857	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
USNM	192092	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
USNM	192093	Geomyidae	Geomyinae	*Geomys*	*pinetis*	F
CM	19481	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
CM	19485	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
CM	59727	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
CM	59728	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
CM	59733	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
UF	1936	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
UF	12330	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
UF	12332	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
USNM	159201	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
USNM	174688	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
USNM	174854	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
USNM	33988	Geomyidae	Geomyinae	*Geomys*	*pinetis*	M
AMNH	131728	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	F
AMNH	139264	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	F
AMNH	139265	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	F
AMNH	139267	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	F
AMNH	139269	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	F
AMNH	139270	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	F
AMNH	139273	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	F
AMNH	139274	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	F
AMNH	135268	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	M
AMNH	139271	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	M
AMNH	139272	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	M
AMNH	139276	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	M
AMNH	139762	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	M
AMNH	139763	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	M
AMNH	139777	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	M
USNM	8627	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	M
FMNH	34942	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	M
FMNH	44016	Geomyidae	Geomyinae	*Heterogeomys*	*heterodus*	F
CM	55782	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	F
CM	55783	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	F
CM	55784	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	F
CM	55785	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	F
CM	112140	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	F
CM	112141	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	F
CM	112142	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	F
CM	112145	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	F

CM	55787	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	M
CM	112146	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	M
USNM	81226	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	M
USNM	92796	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	M
USNM	92986	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	M
USNM	92988	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	M
USNM	92990	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	M
FMNH	13832	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	M
FMNH	13833	Geomyidae	Geomyinae	*Heterogeomys*	*hispidus*	F
USNM	66752	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	67031	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	67032	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	70585	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	71263	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	74625	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	76739	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	126537	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	307608	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	536818	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	536819	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	536821	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	66753	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	67029	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	70048	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	71317	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	74626	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	74630	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	307609	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	535016	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	535016	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	536820	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	536820	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	75949	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	126536	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	F
USNM	66751	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	67030	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	70586	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
USNM	76745	Geomyidae	Geomyinae	*Orthogeomys*	*grandis*	M
CM	55788	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
CM	55789	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
CM	55790	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
CM	55791	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F

LACM	13022	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
LACM	33904	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
LACM	58838	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
LACM	58845	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
USNM	46215	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
USNM	509044	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
USNM	509045	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
USNM	509046	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	F
AMNH	4303	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
LACM	29192	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
LACM	29195	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
LACM	29200	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
LACM	29203	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
LACM	29208	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
LACM	58843	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
LACM	58846	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
USNM	82189	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
USNM	88117	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
USNM	88121	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
USNM	88124	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
USNM	34138	Geomyidae	Geomyinae	*Pappogeomys*	*bulleri*	M
CM	12379	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
CM	12385	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
CM	12388	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
CM	74294	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
CM	74297	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
CM	83633	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
CMNH	7398	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
CMNH	15428	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
CMNH	15429	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	14165	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	36373	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	36970	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	39119	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	46074	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	50343	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	58958	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	59466	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	60051	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	61336	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	62079	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	62085	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F

MVZ:Mamm	82221	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	82247	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
MVZ:Mamm	90315	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
UVM	702	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
UVM	12158	Geomyidae	Geomyinae	*Thomomys*	*bottae*	F
CM	1457	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
CM	12384	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
CM	74292	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
CMNH	7396	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
CMNH	7397	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	10617	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	10618	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	14181	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	37126	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	41688	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	43971	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	43980	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	49053	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	49062	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	57613	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
MVZ:Mamm	66627	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
USNM	63950	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
USNM	63955	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
USNM	64123	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
USNM	64128	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
UVM	12152	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
UVM	12161	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
USNM	244372	Geomyidae	Geomyinae	*Thomomys*	*bottae*	M
AMNH	121121	Geomyidae	Geomyinae	*Thomomys*	*monticola*	F
CM	7220	Geomyidae	Geomyinae	*Thomomys*	*monticola*	F
CM	7221	Geomyidae	Geomyinae	*Thomomys*	*monticola*	F
CM	65261	Geomyidae	Geomyinae	*Thomomys*	*monticola*	F
CM	65267	Geomyidae	Geomyinae	*Thomomys*	*monticola*	F
CM	65268	Geomyidae	Geomyinae	*Thomomys*	*monticola*	F
AMNH	121120	Geomyidae	Geomyinae	*Thomomys*	*monticola*	M
AMNH	121123	Geomyidae	Geomyinae	*Thomomys*	*monticola*	M
CM	65263	Geomyidae	Geomyinae	*Thomomys*	*monticola*	M
CM	71365	Geomyidae	Geomyinae	*Thomomys*	*monticola*	M
CM	71370	Geomyidae	Geomyinae	*Thomomys*	*monticola*	M
CM	71371	Geomyidae	Geomyinae	*Thomomys*	*monticola*	M
CM	71374	Geomyidae	Geomyinae	*Thomomys*	*monticola*	M
CM	84410	Geomyidae	Geomyinae	*Thomomys*	*monticola*	M

USNM	95152	Geomyidae	Geomyinae	*Thomomys*	*monticola*	M
CMNH	298	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
CMNH	765	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
CMNH	2615	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
CMNH	5592	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
CMNH	5621	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
CMNH	11862	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
CMNH	15447	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
CMNH	21494	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
MVZ:Mamm	77301	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
MVZ:Mamm	84518	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
CMNH	717	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
CMNH	720	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
CMNH	11861	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
CMNH	11865	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
CMNH	21496	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
MVZ:Mamm	66403	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
MVZ:Mamm	97909	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
USNM	213345	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
USNM	213614	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
USNM	213826	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
USNM	24267	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
USNM	67096	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
USNM	91066	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
USNM	150725	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
USNM	158079	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	F
USNM	91073	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
USNM	158072	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
USNM	28781	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
USNM	242445	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
USNM	248222	Geomyidae	Geomyinae	*Thomomys*	*talpoides*	M
MVZ:Mamm	46507	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
USNM	65819	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
USNM	65820	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
USNM	168279	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
USNM	168280	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
USNM	168283	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
USNM	179639	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
USNM	179640	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
USNM	181193	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
MVZ:Mamm	35271	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
USNM	168281	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M

USNM	168282	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
USNM	168284	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
USNM	168370	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
USNM	168371	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
USNM	168483	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
USNM	171566	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
USNM	179628	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
MVZ:Mamm	7855	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
MVZ:Mamm	67490	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
MVZ:Mamm	70583	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	F
USNM	264805	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
USNM	181196	Geomyidae	Geomyinae	*Thomomys*	*townsendii*	M
CM	55851	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
CM	55852	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
CM	55853	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
CM	55854	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
CM	55856	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
CM	55866	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
CM	55867	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
CM	55855	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
MVZ:Mamm	100151	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	55922	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	64091	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	64092	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	329707	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	329715	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	329718	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	329722	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	90834	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	96458	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	250887	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	M
USNM	96451	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
USNM	55622	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
USNM	250893	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
USNM	51885	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
USNM	50130	Geomyidae	Geomyinae	*Thomomys*	*umbrinus*	F
USNM	50103	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F
USNM	50105	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F
USNM	125689	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F
USNM	125690	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F
USNM	125691	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F
USNM	125692	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F

USNM	125693	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F
USNM	125962	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F
USNM	125963	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F
USNM	125969	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	F
CM	55902	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
USNM	47186	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
USNM	50099	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
USNM	50100	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
USNM	125966	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
USNM	125967	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
USNM	125968	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
USNM	125970	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
USNM	126246	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
USNM	50107	Geomyidae	Geomyinae	*Zygogeomys*	*trichopus*	M
AMNH	31898	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	F
AMNH	136973	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	F
CM	46366	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	F
CM	75171	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	F
CM	108271	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	F
CM	108272	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	F
USNM	24775	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	F
USNM	248002	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	F
AMNH	31897	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	M
AMNH	136979	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	M
AMNH	136981	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	M
AMNH	136982	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	M
AMNH	136983	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	M
CM	46368	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	M
CM	91071	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	M
USNM	17838	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	F
FMNH	52831	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	M
FMNH	52832	Heteromyidae	Perognathinae	*Chaetodipus*	*baileyi*	M
CM	71387	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	F
CM	71391	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	F
CM	84419	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	F
CM	84422	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	F
CM	84423	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	F
USNM	56555	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	F
USNM	69438	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	F
USNM	120016	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	F
CM	51893	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
CM	71383	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M

CM	71386	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
CM	71389	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
CM	84424	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
CMNH	15384	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
MVZ:Mamm	44094	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
MVZ:Mamm	81550	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
MVZ:Mamm	81579	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
USNM	69439	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
USNM	117789	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
USNM	32116	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	M
USNM	186506	Heteromyidae	Perognathinae	*Chaetodipus*	*californicus*	F
CM	16235	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	F
CM	16298	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	F
CM	48704	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	F
CM	65332	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	F
CM	65334	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	F
CM	89207	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	F
USNM	91877	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	F
USNM	348445	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	F
CM	48699	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	M
CM	48701	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	M
CM	48702	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	M
CM	65333	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	M
CM	65337	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	M
CM	65338	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	M
CM	91055	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	M
CM	108273	Heteromyidae	Perognathinae	*Chaetodipus*	*hispidus*	M
CM	91068	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CM	91069	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CM	91070	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CM	91077	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CM	91079	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CM	108274	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CM	108275	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CMNH	4878	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CMNH	4893	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CMNH	4895	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CMNH	4897	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CMNH	5061	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
UVM	12179	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CM	91067	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
CM	91074	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M

CM	91076	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
CM	91078	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
CM	108277	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
CMNH	5047	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
MVZ:Mamm	50595	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
MVZ:Mamm	55883	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
MVZ:Mamm	55964	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
OSUM	1641	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
OSUM	1642	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
OSUM	1643	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
OSUM	1644	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
OSUM	1645	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
OSUM	1646	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
OSUM	1647	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
UVM	12178	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	M
USNM	203003	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
USNM	564498	Heteromyidae	Perognathinae	*Chaetodipus*	*intermedius*	F
CM	5520	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
CM	12398	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
CM	12401	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
CM	108288	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
CM	117040	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
CM	117041	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
CMNH	15381	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
OSUM	2432	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
OSUM	2437	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
OSUM	2438	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
OSUM	2439	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	F
CM	5528	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
CM	75183	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
CM	108285	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
CM	108289	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
CM	108290	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
OSUM	1640	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
OSUM	2431	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
OSUM	2433	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
OSUM	2434	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
OSUM	2435	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
OSUM	2436	Heteromyidae	Perognathinae	*Chaetodipus*	*penicillatus*	M
CMNH	6438	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	F
CMNH	11511	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	F
UF	1810	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	F

USNM	126022	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	F
USNM	136615	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	F
USNM	136619	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	F
USNM	136621	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	F
USNM	137277	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	F
USNM	149752	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	F
CMNH	6481	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
UF	428	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
USNM	20220	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
USNM	136616	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
USNM	136617	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
USNM	136618	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
USNM	136622	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
USNM	137278	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
USNM	149751	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
USNM	242306	Heteromyidae	Dipodomyinae	*Dipodomys*	*deserti*	M
CM	61020	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
CM	61027	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
CM	61029	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
CM	84429	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
CM	84434	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
USNM	43499	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
USNM	64310	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
USNM	127158	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
AMNH	124164	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
CM	61021	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
CM	71409	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
CM	72275	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
CM	72280	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
CM	72283	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
CM	84435	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
MVZ:Mamm	14440	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
MVZ:Mamm	26805	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
MVZ:Mamm	28729	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
MVZ:Mamm	29087	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
MVZ:Mamm	84840	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
USNM	118924	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	M
FMNH	12925	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
FMNH	13021	Heteromyidae	Dipodomyinae	*Dipodomys*	*heermanni*	F
USNM	128802	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	F
USNM	128803	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	F
USNM	140321	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	F

USNM	149734	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	F
USNM	150535	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	F
USNM	150537	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	F
USNM	151324	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	F
USNM	177691	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	F
USNM	128801	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	M
USNM	128804	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	M
USNM	140322	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	M
USNM	149733	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	M
USNM	150402	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	M
USNM	151321	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	M
USNM	151323	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	M
USNM	177690	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	M
USNM	128805	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	M
CMNH	5035	Heteromyidae	Dipodomyinae	*Dipodomys*	*ingens*	F
CMNH	5039	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	5042	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	5062	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	5064	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	5106	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	6253	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	6254	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	6330	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	6405	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	6417	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	6474	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	6519	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
CMNH	6606	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2371	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2373	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2377	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2661	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2663	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2667	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2668	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2673	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2676	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2678	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	2680	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	F
OSUM	1637	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	1638	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	1639	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M

OSUM	2372	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2374	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2375	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2376	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2404	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2658	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2659	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2660	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2662	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2664	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2665	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2669	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2670	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2671	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2672	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2674	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2675	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2677	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2679	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2681	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2715	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
OSUM	2785	Heteromyidae	Dipodomyinae	*Dipodomys*	*merriami*	M
CMNH	893	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
CMNH	4988	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
CMNH	11184	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2378	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2386	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2387	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2638	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2639	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2644	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2645	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2648	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2650	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2653	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2714	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2716	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2717	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
OSUM	2784	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
UVM	323	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
UVM	1465	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F
UVM	1859	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	F

OSUM	2379	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2381	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2382	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2383	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2384	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2385	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2635	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2636	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2640	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2642	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2643	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2646	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2647	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2649	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2651	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2652	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
OSUM	2713	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
UVM	1817	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
UVM	1860	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
UVM	1861	Heteromyidae	Dipodomyinae	*Dipodomys*	*ordii*	M
AMNH	6819	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	F
AMNH	6821	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	F
AMNH	68325	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	F
AMNH	145387	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	F
CM	46567	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	F
CM	108316	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	F
LACM	20848	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	F
MVZ:Mamm	82782	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	F
USNM	17748	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	F
CM	46566	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	M
CM	55925	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	M
CM	108314	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	M
USNM	17886	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	M
USNM	78953	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	M
USNM	96432	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	M
USNM	97185	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	M
USNM	158824	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	M
FMNH	788	Heteromyidae	Dipodomyinae	*Dipodomys*	*spectabilis*	M
CM	848	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	F
CM	3125	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	F
CM	3131	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	F
CM	3145	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	F

CM	3160	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	F
CM	78170	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	F
CM	78171	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	F
USNM	143794	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	F
CM	838	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	M
CM	3126	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	M
CM	78173	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	M
CM	78751	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	M
USNM	102736	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	M
USNM	317699	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	M
USNM	317705	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	M
USNM	317706	Heteromyidae	Heteromyinae	*Heteromys*	*anomalus*	M
CM	118618	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	F
CM	118619	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	F
CM	118620	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	F
CM	118621	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	F
CM	118622	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	F
UF	24801	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	F
USNM	63719	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	F
USNM	170976	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	F
USNM	250348	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	F
CM	91951	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	M
CM	118624	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	M
CM	118628	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	M
CM	118632	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	M
CM	118635	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	M
CM	118639	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	M
USNM	171107	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	M
USNM	179016	Heteromyidae	Heteromyinae	*Heteromys*	*desmarestianus*	M
CM	92771	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	F
CM	92772	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	F
CM	92775	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	F
CM	92776	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	F
CM	92788	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	F
CM	92789	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	F
CM	92790	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	F
CM	92791	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	F
AMNH	91195	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	M
AMNH	91197	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	M
CM	92773	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	M
CM	92774	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	M
CM	92785	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	M

CM	92786	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	M
CM	92787	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	M
CM	92792	Heteromyidae	Heteromyinae	*Heteromys*	*gaumeri*	M
CM	55928	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
CM	55929	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
CM	55931	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
CM	55932	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
CM	75312	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
CM	75315	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
CM	79452	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
OSUM	1271	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
USNM	58670	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
USNM	69645	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
USNM	70301	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	F
CM	16222	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
CM	55927	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
CM	55930	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
USNM	50342	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
USNM	50343	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
USNM	50344	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
USNM	50345	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
USNM	50348	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
USNM	93097	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
USNM	96259	Heteromyidae	Heteromyinae	*Heteromys*	*irroratus*	M
CM	103542	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	F
CM	103557	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	F
CM	103560	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	F
CM	103564	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	F
CM	103566	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	F
CMNH	13701	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	F
UF	6168	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	F
UF	6176	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	F
UF	6182	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	F
CM	103541	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M
CM	103543	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M
CM	103555	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M
CM	103556	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M
CM	103565	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M
CM	103575	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M
CMNH	13700	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M
UF	6173	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M
UF	6175	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M

USNM	71510	Heteromyidae	Heteromyinae	*Heteromys*	*pictus*	M
MVZ:Mamm	73890	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
MVZ:Mamm	160039	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
USNM	68081	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
USNM	78217	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
USNM	101230	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
USNM	244584	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
USNM	244586	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
MVZ:Mamm	17031	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
MVZ:Mamm	49381	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
MVZ:Mamm	52803	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
MVZ:Mamm	70917	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
MVZ:Mamm	73840	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
MVZ:Mamm	74660	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
USNM	78216	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
USNM	101226	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
USNM	101228	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
USNM	101229	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
USNM	246039	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
USNM	101227	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
USNM	80128	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
USNM	24417	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	M
FMNH	51858	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
FMNH	52732	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
FMNH	52733	Heteromyidae	Dipodomyinae	*Microdipodops*	*megacephalus*	F
CM	17073	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
CM	17076	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
CM	17092	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
CM	18073	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
CM	18075	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
CM	18077	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
CM	46574	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
MVZ:Mamm	49254	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
MVZ:Mamm	58208	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
CM	17077	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
CM	17081	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
CM	17083	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
CM	17086	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
CM	17087	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
CM	17094	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
CM	17095	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
CM	18072	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M

CM	18074	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
MVZ:Mamm	52753	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
USNM	210397	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	M
USNM	93520	Heteromyidae	Dipodomyinae	*Microdipodops*	*pallidus*	F
AMNH	204525	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	F
AMNH	204527	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	F
AMNH	204528	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	F
CM	12696	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	F
CM	45243	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	F
CM	45245	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	F
USNM	57725	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	F
USNM	97416	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	F
CM	45242	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	M
CM	65329	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	M
CM	65330	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	M
USNM	4984	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	M
USNM	5027	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	M
USNM	148206	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	M
USNM	150768	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	M
USNM	226344	Heteromyidae	Perognathinae	*Perognathus*	*flavescens*	M
CM	61212	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	F
USNM	34618	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	F
USNM	202610	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	F
USNM	213440	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	F
USNM	214154	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	F
USNM	248014	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	F
USNM	250885	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	F
USNM	260736	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	F
CM	4785	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	M
CM	75173	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	M
CM	91028	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	M
CM	108293	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	M
CMNH	11178	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	M
USNM	34619	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	M
USNM	34620	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	M
USNM	50714	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	M
USNM	168650	Heteromyidae	Perognathinae	*Perognathus*	*flavus*	M
CMNH	6663	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
CMNH	6723	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
CMNH	16729	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
MVZ:Mamm	74680	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
MVZ:Mamm	78764	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F

USNM	15780	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
USNM	15782	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
USNM	28723	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
USNM	31130	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
USNM	247994	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
CMNH	6618	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
CMNH	6619	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
CMNH	6719	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
CMNH	11488	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
CMNH	11537	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
MVZ:Mamm	58624	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
MVZ:Mamm	74668	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
USNM	54084	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
USNM	117224	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
USNM	117225	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
USNM	250032	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	F
USNM	27767	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
USNM	136123	Heteromyidae	Perognathinae	*Perognathus*	*longimembris*	M
CM	15639	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
CM	15642	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
CM	19052	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
CM	22025	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
CM	46422	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
CMNH	11729	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
CMNH	11879	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
CMNH	15386	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
UVM	7696	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
CM	15640	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
CM	15643	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
CM	19056	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
CM	19058	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
CM	46423	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
CM	46424	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
CMNH	6854	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
CMNH	15944	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
MVZ:Mamm	16154	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
MVZ:Mamm	60929	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
UVM	12181	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
USNM	36760	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
USNM	27351	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	M
FMNH	198349	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F
FMNH	7205	Heteromyidae	Perognathinae	*Perognathus*	*parvus*	F

Appendix 2: Results for the post-hoc Tukey tests for the analysis of size, for species within Geomyidae.

Species 1	Species 2	Post-hoc test p value
Cratogeomys fumosus	*Cratogeomys castanops*	0
Cratogeomys merriami	*Cratogeomys castanops*	0
Geomys arenarius	*Cratogeomys castanops*	0
Geomys bursarius	*Cratogeomys castanops*	0.262
Geomys personatus	*Cratogeomys castanops*	0
Geomys pinetis	*Cratogeomys castanops*	0.002
Heterogeomys heterodus	*Cratogeomys castanops*	0
Heterogeomys hispidus	*Cratogeomys castanops*	0
Orthogeomys grandis	*Cratogeomys castanops*	0
Pappogeomys bulleri	*Cratogeomys castanops*	0
Thomomys bottae	*Cratogeomys castanops*	0
Thomomys monticola	*Cratogeomys castanops*	0
Thomomys talpoides	*Cratogeomys castanops*	0
Thomomys townsendii	*Cratogeomys castanops*	0.006
Thomomys umbrinus	*Cratogeomys castanops*	0
Zygogeomys trichopus	*Cratogeomys castanops*	0.215
Cratogeomys merriami	*Cratogeomys fumosus*	0.934
Geomys arenarius	*Cratogeomys fumosus*	0
Geomys bursarius	*Cratogeomys fumosus*	0
Geomys personatus	*Cratogeomys fumosus*	0
Geomys pinetis	*Cratogeomys fumosus*	0
Heterogeomys heterodus	*Cratogeomys fumosus*	0.89
Heterogeomys hispidus	*Cratogeomys fumosus*	1
Orthogeomys grandis	*Cratogeomys fumosus*	0.003
Pappogeomys bulleri	*Cratogeomys fumosus*	0
Thomomys bottae	*Cratogeomys fumosus*	0

Thomomys monticola	*Cratogeomys fumosus*	0
Thomomys talpoides	*Cratogeomys fumosus*	0
Thomomys townsendii	*Cratogeomys fumosus*	0
Thomomys umbrinus	*Cratogeomys fumosus*	0
Zygogeomys trichopus	*Cratogeomys fumosus*	0.101
Geomys arenarius	*Cratogeomys merriami*	0
Geomys bursarius	*Cratogeomys merriami*	0
Geomys personatus	*Cratogeomys merriami*	0
Geomys pinetis	*Cratogeomys merriami*	0
Heterogeomys heterodus	*Cratogeomys merriami*	0.024
Heterogeomys hispidus	*Cratogeomys merriami*	0.258
Orthogeomys grandis	*Cratogeomys merriami*	0
Pappogeomys bulleri	*Cratogeomys merriami*	0
Thomomys bottae	*Cratogeomys merriami*	0
Thomomys monticola	*Cratogeomys merriami*	0
Thomomys talpoides	*Cratogeomys merriami*	0
Thomomys townsendii	*Cratogeomys merriami*	0
Thomomys umbrinus	*Cratogeomys merriami*	0
Zygogeomys trichopus	*Cratogeomys merriami*	0.975
Geomys bursarius	*Geomys arenarius*	0
Geomys pinetis	*Geomys arenarius*	0.854
Geomys pinetis	*Geomys arenarius*	0
Heterogeomys heterodus	*Geomys arenarius*	0
Heterogeomys hispidus	*Geomys arenarius*	0
Orthogeomys grandis	*Geomys arenarius*	0
Pappogeomys bulleri	*Geomys arenarius*	0.985
Thomomys bottae	*Geomys arenarius*	0.586
Thomomys monticola	*Geomys arenarius*	0
Thomomys talpoides	*Geomys arenarius*	0
Thomomys townsendii	*Geomys arenarius*	0
Thomomys umbrinus	*Geomys arenarius*	0.005
Zygogeomys trichopus	*Geomys arenarius*	0
Geomys personatus	*Geomys bursarius*	0.062

Geomys pinetis	*Geomys bursarius*	1
Heterogeomys heterodus	*Geomys bursarius*	0
Heterogeomys hispidus	*Geomys bursarius*	0
Orthogeomys grandis	*Geomys bursarius*	0
Pappogeomys bulleri	*Geomys bursarius*	0
Thomomys bottae	*Geomys bursarius*	0
Thomomys monticola	*Geomys bursarius*	0
Thomomys talpoides	*Geomys bursarius*	0
Thomomys townsendii	*Geomys bursarius*	1
Thomomys umbrinus	*Geomys bursarius*	0
Zygogeomys trichopus	*Geomys bursarius*	0
Geomys pinetis	*Geomys personatus*	0.346
Heterogeomys heterodus	*Geomys personatus*	0
Heterogeomys hispidus	*Geomys personatus*	0
Orthogeomys grandis	*Geomys personatus*	0
Pappogeomys bulleri	*Geomys personatus*	0.039
Thomomys bottae	*Geomys personatus*	0
Thomomys monticola	*Geomys personatus*	0
Thomomys talpoides	*Geomys personatus*	0
Thomomys townsendii	*Geomys personatus*	0.379
Thomomys umbrinus	*Geomys personatus*	0
Zygogeomys trichopus	*Geomys personatus*	0
Heterogeomys heterodus	*Geomys pinetis*	0
Heterogeomys hispidus	*Geomys pinetis*	0
Orthogeomys grandis	*Geomys pinetis*	0
Pappogeomys bulleri	*Geomys pinetis*	0
Thomomys bottae	*Geomys pinetis*	0
Thomomys monticola	*Geomys pinetis*	0
Thomomys talpoides	*Geomys pinetis*	0
Thomomys townsendii	*Geomys pinetis*	1
Thomomys umbrinus	*Geomys pinetis*	0
Zygogeomys trichopus	*Geomys pinetis*	0
Heterogeomys hispidus	*Heterogeomys heterodus*	1

Orthogeomys grandis	*Heterogeomys heterodus*	0.88
Pappogeomys bulleri	*Heterogeomys heterodus*	0
Thomomys bottae	*Heterogeomys heterodus*	0
Thomomys monticola	*Heterogeomys heterodus*	0
Thomomys talpoides	*Heterogeomys heterodus*	0
Thomomys townsendii	*Heterogeomys heterodus*	0
Thomomys umbrinus	*Heterogeomys heterodus*	0
Zygogeomys trichopus	*Heterogeomys heterodus*	0
Orthogeomys grandis	*Heterogeomys hispidus*	0.368
Pappogeomys bulleri	*Heterogeomys hispidus*	0
Thomomys bottae	*Heterogeomys hispidus*	0
Thomomys monticola	*Heterogeomys hispidus*	0
Thomomys talpoides	*Heterogeomys hispidus*	0
Thomomys townsendii	*Heterogeomys hispidus*	0
Thomomys umbrinus	*Heterogeomys hispidus*	0
Zygogeomys trichopus	*Heterogeomys hispidus*	0.004
Pappogeomys bulleri	*Orthogeomys grandis*	0
Thomomys bottae	*Orthogeomys grandis*	0
Thomomys monticola	*Orthogeomys grandis*	0
Thomomys talpoides	*Orthogeomys grandis*	0
Thomomys townsendii	*Orthogeomys grandis*	0
Thomomys umbrinus	*Orthogeomys grandis*	0
Zygogeomys trichopus	*Orthogeomys grandis*	0
Thomomys bottae	*Pappogeomys bulleri*	1
Thomomys monticola	*Pappogeomys bulleri*	0
Thomomys talpoides	*Pappogeomys bulleri*	0.002
Thomomys townsendii	*Pappogeomys bulleri*	0
Thomomys umbrinus	*Pappogeomys bulleri*	0.258
Zygogeomys trichopus	*Pappogeomys bulleri*	0
Thomomys monticola	*Thomomys bottae*	0
Thomomys talpoides	*Thomomys bottae*	0.002
Thomomys townsendii	*Thomomys bottae*	0
Thomomys umbrinus	*Thomomys bottae*	0.486

Zygogeomys trichopus	*Thomomys bottae*	0
Thomomys talpoides	*Thomomys monticola*	0
Thomomys townsendii	*Thomomys monticola*	0
Thomomys umbrinus	*Thomomys monticola*	0
Zygogeomys trichopus	*Thomomys monticola*	0
Thomomys townsendii	*Thomomys talpoides*	0
Thomomys umbrinus	*Thomomys talpoides*	1
Zygogeomys trichopus	*Thomomys talpoides*	0
Thomomys umbrinus	*Thomomys townsendii*	0
Zygogeomys trichopus	*Thomomys townsendii*	0
Zygogeomys trichopus	*Thomomys umbrinus*	0

Appendix 3: Results for the post-hoc Tukey tests for the analysis of size, for species within Heteromyidae.

Species 1	Species 2	Post-hoc test p value
Chaetodipus californicus	*Chaetodipus baileyi*	0
Chaetodipus hispidus	*Chaetodipus baileyi*	0.055
Chaetodipus intermedius	*Chaetodipus baileyi*	0
Chaetodipus penicillatus	*Chaetodipus baileyi*	0
Dipodomys deserti	*Chaetodipus baileyi*	0
Dipodomys heermanni	*Chaetodipus baileyi*	0
Dipodomys ingens	*Chaetodipus baileyi*	0
Dipodomys merriami	*Chaetodipus baileyi*	0
Dipodomys ordii	*Chaetodipus baileyi*	0
Dipodomys spectabilis	*Chaetodipus baileyi*	0
Heteromys anomalus	*Chaetodipus baileyi*	0
Heteromys desmarestianus	*Chaetodipus baileyi*	0
Heteromys gaumeri	*Chaetodipus baileyi*	0
Heteromys irroratus	*Chaetodipus baileyi*	0
Heteromys pictus	*Chaetodipus baileyi*	0.009
Microdipodops megacephalus	*Chaetodipus baileyi*	0

Microdipodops pallidus	*Chaetodipus baileyi*	0
Perognathus flavescens	*Chaetodipus baileyi*	0
Perognathus flavus	*Chaetodipus baileyi*	0
Perognathus longimembris	*Chaetodipus baileyi*	0
Perognathus parvus	*Chaetodipus baileyi*	0
Chaetodipus hispidus	*Chaetodipus californicus*	0
Chaetodipus intermedius	*Chaetodipus californicus*	0
Chaetodipus penicillatus	*Chaetodipus californicus*	0.753
Dipodomys deserti	*Chaetodipus californicus*	0
Dipodomys heermanni	*Chaetodipus californicus*	0
Dipodomys ingens	*Chaetodipus californicus*	0
Dipodomys merriami	*Chaetodipus californicus*	0
Dipodomys ordii	*Chaetodipus californicus*	0
Dipodomys spectabilis	*Chaetodipus californicus*	0
Heteromys anomalus	*Chaetodipus californicus*	0
Heteromys desmarestianus	*Chaetodipus californicus*	0
Heteromys gaumeri	*Chaetodipus californicus*	0
Heteromys irroratus	*Chaetodipus californicus*	0
Heteromys pictus	*Chaetodipus californicus*	0
Microdipodops megacephalus	*Chaetodipus californicus*	1
Microdipodops pallidus	*Chaetodipus californicus*	1
Perognathus flavescens	*Chaetodipus californicus*	0
Perognathus flavus	*Chaetodipus californicus*	0
Perognathus longimembris	*Chaetodipus californicus*	0
Perognathus parvus	*Chaetodipus californicus*	0.287
Chaetodipus intermedius	*Chaetodipus hispidus*	0
Chaetodipus penicillatus	*Chaetodipus hispidus*	0
Dipodomys deserti	*Chaetodipus hispidus*	0
Dipodomys heermanni	*Chaetodipus hispidus*	0
Dipodomys ingens	*Chaetodipus hispidus*	0
Dipodomys merriami	*Chaetodipus hispidus*	0
Dipodomys ordii	*Chaetodipus hispidus*	0
Dipodomys spectabilis	*Chaetodipus hispidus*	0

Heteromys anomalus	*Chaetodipus hispidus*	0
Heteromys desmarestianus	*Chaetodipus hispidus*	0
Heteromys gaumeri	*Chaetodipus hispidus*	0.005
Heteromys irroratus	*Chaetodipus hispidus*	0.949
Heteromys pictus	*Chaetodipus hispidus*	1
Microdipodops megacephalus	*Chaetodipus hispidus*	0
Microdipodops pallidus	*Chaetodipus hispidus*	0
Perognathus flavescens	*Chaetodipus hispidus*	0
Perognathus flavus	*Chaetodipus hispidus*	0
Perognathus longimembris	*Chaetodipus hispidus*	0
Perognathus parvus	*Chaetodipus hispidus*	0
Chaetodipus penicillatus	*Chaetodipus intermedius*	0
Dipodomys deserti	*Chaetodipus intermedius*	0
Dipodomys heermanni	*Chaetodipus intermedius*	0
Dipodomys ingens	*Chaetodipus intermedius*	0
Dipodomys merriami	*Chaetodipus intermedius*	0
Dipodomys ordii	*Chaetodipus intermedius*	0
Dipodomys spectabilis	*Chaetodipus intermedius*	0
Heteromys anomalus	*Chaetodipus intermedius*	0
Heteromys desmarestianus	*Chaetodipus intermedius*	0
Heteromys gaumeri	*Chaetodipus intermedius*	0
Heteromys irroratus	*Chaetodipus intermedius*	0
Heteromys pictus	*Chaetodipus intermedius*	0
Microdipodops megacephalus	*Chaetodipus intermedius*	0
Microdipodops pallidus	*Chaetodipus intermedius*	0
Perognathus flavescens	*Chaetodipus intermedius*	0.011
Perognathus flavus	*Chaetodipus intermedius*	0
Perognathus longimembris	*Chaetodipus intermedius*	0
Perognathus parvus	*Chaetodipus intermedius*	0
Dipodomys deserti	*Chaetodipus penicillatus*	0
Dipodomys heermanni	*Chaetodipus penicillatus*	0
Dipodomys ingens	*Chaetodipus penicillatus*	0
Dipodomys merriami	*Chaetodipus penicillatus*	0

Dipodomys ordii	*Chaetodipus penicillatus*	0
Dipodomys spectabilis	*Chaetodipus penicillatus*	0
Heteromys anomalus	*Chaetodipus penicillatus*	0
Heteromys desmarestianus	*Chaetodipus penicillatus*	0
Heteromys gaumeri	*Chaetodipus penicillatus*	0
Heteromys irroratus	*Chaetodipus penicillatus*	0
Heteromys pictus	*Chaetodipus penicillatus*	0
Microdipodops megacephalus	*Chaetodipus penicillatus*	1
Microdipodops pallidus	*Chaetodipus penicillatus*	0.473
Perognathus flavescens	*Chaetodipus penicillatus*	0
Perognathus flavus	*Chaetodipus penicillatus*	0
Perognathus longimembris	*Chaetodipus penicillatus*	0
Perognathus parvus	*Chaetodipus penicillatus*	1
Dipodomys heermanni	*Dipodomys deserti*	0
Dipodomys ingens	*Dipodomys deserti*	0.887
Dipodomys merriami	*Dipodomys deserti*	0
Dipodomys ordii	*Dipodomys deserti*	0
Dipodomys spectabilis	*Dipodomys deserti*	0.011
Heteromys anomalus	*Dipodomys deserti*	0
Heteromys desmarestianus	*Dipodomys deserti*	0
Heteromys gaumeri	*Dipodomys deserti*	0
Heteromys irroratus	*Dipodomys deserti*	0
Heteromys pictus	*Dipodomys deserti*	0
Microdipodops megacephalus	*Dipodomys deserti*	0
Microdipodops pallidus	*Dipodomys deserti*	0
Perognathus flavescens	*Dipodomys deserti*	0
Perognathus flavus	*Dipodomys deserti*	0
Perognathus longimembris	*Dipodomys deserti*	0
Perognathus parvus	*Dipodomys deserti*	0
Dipodomys ingens	*Dipodomys heermanni*	0
Dipodomys deserti	*Dipodomys heermanni*	0
Dipodomys ordii	*Dipodomys heermanni*	0.028
Dipodomys spectabilis	*Dipodomys heermanni*	0

Heteromys anomalus	*Dipodomys heermanni*	0
Heteromys desmarestianus	*Dipodomys heermanni*	0
Heteromys gaumeri	*Dipodomys heermanni*	0
Heteromys irroratus	*Dipodomys heermanni*	0
Heteromys pictus	*Dipodomys heermanni*	0
Microdipodops megacephalus	*Dipodomys heermanni*	0
Microdipodops pallidus	*Dipodomys heermanni*	0
Perognathus flavescens	*Dipodomys heermanni*	0
Perognathus flavus	*Dipodomys heermanni*	0
Perognathus longimembris	*Dipodomys heermanni*	0
Perognathus parvus	*Dipodomys heermanni*	0
Dipodomys merriami	*Dipodomys ingens*	0
Dipodomys ordii	*Dipodomys ingens*	0
Dipodomys spectabilis	*Dipodomys ingens*	0.940
Heteromys anomalus	*Dipodomys ingens*	0
Heteromys desmarestianus	*Dipodomys ingens*	0
Heteromys gaumeri	*Dipodomys ingens*	0
Heteromys irroratus	*Dipodomys ingens*	0
Heteromys pictus	*Dipodomys ingens*	0
Microdipodops megacephalus	*Dipodomys ingens*	0
Microdipodops pallidus	*Dipodomys ingens*	0
Perognathus flavescens	*Dipodomys ingens*	0
Perognathus flavus	*Dipodomys ingens*	0
Perognathus longimembris	*Dipodomys ingens*	0
Perognathus parvus	*Dipodomys ingens*	0
Dipodomys ordii	*Dipodomys merriami*	0.003
Dipodomys spectabilis	*Dipodomys merriami*	0
Heteromys anomalus	*Dipodomys merriami*	0.005
Heteromys desmarestianus	*Dipodomys merriami*	0.978
Heteromys gaumeri	*Dipodomys merriami*	0
Heteromys irroratus	*Dipodomys merriami*	0
Heteromys pictus	*Dipodomys merriami*	0
Microdipodops megacephalus	*Dipodomys merriami*	0

Microdipodops pallidus	*Dipodomys merriami*	0
Perognathus flavescens	*Dipodomys merriami*	0
Perognathus flavus	*Dipodomys merriami*	0
Perognathus longimembris	*Dipodomys merriami*	0
Perognathus parvus	*Dipodomys merriami*	0
Dipodomys spectabilis	*Dipodomys ordii*	0
Heteromys anomalus	*Dipodomys ordii*	0
Heteromys desmarestianus	*Dipodomys ordii*	0
Heteromys gaumeri	*Dipodomys ordii*	0
Heteromys irroratus	*Dipodomys ordii*	0
Heteromys pictus	*Dipodomys ordii*	0
Microdipodops megacephalus	*Dipodomys ordii*	0
Microdipodops pallidus	*Dipodomys ordii*	0
Perognathus flavescens	*Dipodomys ordii*	0
Perognathus flavus	*Dipodomys ordii*	0
Perognathus longimembris	*Dipodomys ordii*	0
Perognathus parvus	*Dipodomys ordii*	0
Heteromys anomalus	*Dipodomys spectabilis*	0
Heteromys desmarestianus	*Dipodomys spectabilis*	0
Heteromys gaumeri	*Dipodomys spectabilis*	0
Heteromys irroratus	*Dipodomys spectabilis*	0
Heteromys pictus	*Dipodomys spectabilis*	0
Microdipodops megacephalus	*Dipodomys spectabilis*	0
Microdipodops pallidus	*Dipodomys spectabilis*	0
Perognathus flavescens	*Dipodomys spectabilis*	0
Perognathus flavus	*Dipodomys spectabilis*	0
Perognathus longimembris	*Dipodomys spectabilis*	0
Perognathus parvus	*Dipodomys spectabilis*	0
Heteromys desmarestianus	*Heteromys anomalus*	0.898
Heteromys gaumeri	*Heteromys anomalus*	0.951
Heteromys irroratus	*Heteromys anomalus*	0.001
Heteromys pictus	*Heteromys anomalus*	0
Microdipodops megacephalus	*Heteromys anomalus*	0

Microdipodops pallidus	*Heteromys anomalus*	0
Perognathus flavescens	*Heteromys anomalus*	0
Perognathus flavus	*Heteromys anomalus*	0
Perognathus longimembris	*Heteromys anomalus*	0
Perognathus parvus	*Heteromys anomalus*	0
Heteromys gaumeri	*Heteromys desmarestianus*	0.012
Heteromys irroratus	*Heteromys desmarestianus*	0
Heteromys pictus	*Heteromys desmarestianus*	0
Microdipodops megacephalus	*Heteromys desmarestianus*	0
Microdipodops pallidus	*Heteromys desmarestianus*	0
Perognathus flavescens	*Heteromys desmarestianus*	0
Perognathus flavus	*Heteromys desmarestianus*	0
Perognathus longimembris	*Heteromys desmarestianus*	0
Perognathus parvus	*Heteromys desmarestianus*	0
Heteromys irroratus	*Heteromys gaumeri*	0.550
Heteromys pictus	*Heteromys gaumeri*	0.010
Microdipodops megacephalus	*Heteromys gaumeri*	0
Microdipodops pallidus	*Heteromys gaumeri*	0
Perognathus flavescens	*Heteromys gaumeri*	0
Perognathus flavus	*Heteromys gaumeri*	0
Perognathus longimembris	*Heteromys gaumeri*	0
Perognathus parvus	*Heteromys gaumeri*	0
Heteromys pictus	*Heteromys irroratus*	0.992
Microdipodops megacephalus	*Heteromys irroratus*	0
Microdipodops pallidus	*Heteromys irroratus*	0
Perognathus flavescens	*Heteromys irroratus*	0
Perognathus flavus	*Heteromys irroratus*	0
Perognathus longimembris	*Heteromys irroratus*	0
Perognathus parvus	*Heteromys irroratus*	0
Microdipodops megacephalus	*Heteromys pictus*	0
Microdipodops pallidus	*Heteromys pictus*	0
Perognathus flavescens	*Heteromys pictus*	0
Perognathus flavus	*Heteromys pictus*	0

Perognathus longimembris	*Heteromys pictus*	0
Perognathus parvus	*Heteromys pictus*	0
Microdipodops pallidus	*Microdipodops megacephalus*	1
Perognathus flavescens	*Microdipodops megacephalus*	0
Perognathus flavus	*Microdipodops megacephalus*	0
Perognathus longimembris	*Microdipodops megacephalus*	0
Perognathus parvus	*Microdipodops megacephalus*	0.963
Perognathus flavescens	*Microdipodops pallidus*	0
Perognathus flavus	*Microdipodops pallidus*	0
Perognathus longimembris	*Microdipodops pallidus*	0
Perognathus parvus	*Microdipodops pallidus*	0.116
Perognathus flavus	*Perognathus flavescens*	0.002
Perognathus longimembris	*Perognathus flavescens*	0.893
Perognathus parvus	*Perognathus flavescens*	0
Perognathus longimembris	*Perognathus flavus*	0.458
Perognathus parvus	*Perognathus flavus*	0
Perognathus parvus	*Perognathus longimembris*	0